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AWD Technologies Integrated AquaDetox®/SVE Technology

Applications Analysis Report

Risk Reduction Engineering Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
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Notice

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Foreword

The Superfund Innovative Technology Evaluation (SITE) Program was authorized in the 1986 Superfund Amendments and Reauthorization Act (SARA). The program is a joint effort between EPA's Office of Research and Development (ORD) and Office of Solid Waste and Emergency Response (OSWER). The purpose of the program is to assist in the development of hazardous waste treatment technologies necessary to implement new cleanup standards that require greater reliance on permanent remedies. This is accomplished through technology demonstrations that are designed to provide engineering and cost data on selected technologies.

This report presents the findings of a SITE field demonstration designed to analyze AWD Technologies' integrated **AquaDetox®/soil** vapor extraction technology. The technology demonstration took place at the Lockheed Aeronautical Systems Company site in Burbank, California. The demonstration effort was directed to obtain information on the performance and cost of the technology and to assess its use at this and other uncontrolled hazardous waste sites. Documentation consists of two reports: (1) a Technology Evaluation Report (TER) that describes the field activities and laboratory results and (2) this Applications Analysis Report (AAR) that provides an interpretation of the data and discusses the potential applicability of the technology.

An extensive Quality Assurance (QA) program was conducted according to EPA QA guidelines, including audits, data reviews, and corrective action plans. This program is the basis for the quality of the data derived from the SITE project. Discussions of the QA program and the results of the audits, data reviews, and corrective action plans can be found in the TER.

A limited number of copies of this report will be available at no charge from EPA's Center for Environmental Research Information (CERI), 26 West Martin Luther King Drive, Cincinnati, Ohio 45268. Requests should include the EPA document number found on the report's cover. When the limited supply is exhausted, additional copies can be purchased from the National Technical Information Service (NTIS), Ravensworth Building, Springfield, Virginia 22151, 703/1487-4600. Reference copies will be available at EPA libraries in the Hazardous Waste Collection. You can also call the SITE Clearinghouse hotline at 800/424-9346 or 202/382-3000 in Washington, D.C., to inquire about the availability of other reports.

Abstract

In support of the U.S. Environmental Protection Agency's (EPA) Superfund Innovative Technology Evaluation (SITE) Program, this report evaluates the AWD Technologies, Inc., integrated **AquaDetox®/SVE** treatment system for simultaneous on-site treatment of contaminated groundwater and soil-gas. The AWD technology uses an **AquaDetox®** moderate vacuum steam stripping system to treat contaminated groundwater and a soil vapor extraction (SVE) system that uses granular activated carbon (GAC) beds to treat soil-gas. The two systems are looped together to form a closed system with no emissions. This report evaluates both the treatment efficiency and economic data based on results from the SITE demonstration and describes several case studies.

Under the SITE Program, the AWD technology was demonstrated at the Lockheed site in Burbank, California, in September 1990. The groundwater and soil at the Lockheed site were contaminated with volatile organic compounds (VOC), primarily trichloroethylene (TCE) and tetrachloroethylene (PCE). Extensive sampling and analyses were performed on the groundwater and soil-gas before and after treatment so that system removal efficiencies could be calculated. All sampling and analyses were performed according to quality assurance guidelines outlined by the SITE Program.

The 2-week long SITE demonstration consisted of 21 test runs performed under varying operating conditions. Four operating parameters were varied including: groundwater flow rate, steam flow rate, stripping tower pressure, and GAC bed regeneration frequency. The AWD technology was evaluated based on the removal efficiencies achieved for removal of TCE and PCE from contaminated groundwater and soil-gas. The technology was also evaluated based on compliance of the effluent groundwater with the regulatory discharge requirements at the Lockheed site.

The conclusions drawn from these evaluations are: (1) the system can effectively treat VOC contaminated groundwater and soil-gas; (2) VOC removal efficiencies as high as 99.99 percent can be achieved for groundwater; (3) soil-gas VOC removal efficiencies as high as 99.9 percent can be achieved; (4) the effluent groundwater was in compliance with the regulatory discharge requirements of 5 **μg/L** each for TCE and PCE throughout the demonstration; (5) the system operates more efficiently at lower stripping tower pressures; and (6) the l,OOO-gallons per minute system at Lockheed has an estimated capital cost of $4.3 million and annual operating and maintenance costs of approximately $820,000.

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Abbreviations and Symbols

μg/L	Micrograms per liter
AAR	Applications Analysis Report
ARAR	Applicable or Relevant and Appropriate Requirements
CERCLA	Comprehensive Environmental Response Compensation and Liability Act
CERI	Center for Environmental Research Information
CFR	Code of Federal Regulations
crn/sec	Centimeters per second
CWA	Clean Water Act
EPA	U.S. Environmental Protection Agency
GAC	Granular activated carbon
gpm	Gallon per minute
HSWA	Hazardous Solid Waste Amendments
kW	Kilowatt
kWh	Kilowatt hour
LADWP	Los Angeles Department of Water and Power
LASC	Lockheed Aeronautical Systems Company
lb/hr	Pounds per hour
MCL	Maximum contaminant level
mg/L	Milligrams per liter
mm Hg	Millimeters of mercury
NCP	National Contingency Plan
NIOSH	National Institute for Occupational Safety and Health
NPDES	National Pollutant Discharge Elimination System
NTIS	National Technical Information Service
O&M	Operation and maintenance
ORD	Office of Research and Development
OSHA	Occupational Safety and Health Act
OSWER	Office of Solid Waste and Emergency Response
PCB	Polychlorinated biphenyl

Abbreviations and Symbols (continued)

PCE	Tetrachloroethylene
POTW	Publicly-owned treatment works
ppb	Parts per billion
ppm	Parts per million
PSD	Public Service Department
QA/QC	Quality assurance/quality control
RCRA	Resource Conservation and Recovery Act
RWQCB	Regional Water Quality Control Board
SARA	Superfund Amendments and Reauthorization Act
scfm	Standard cubic feet per minute
SDWA	Safe Drinking Water Act
SFVGB	San Fernando Valley Groundwater Basin
SITE	Superfund Innovative Technology Evaluation
SVE	Soil vapor extraction
SVOC	Semi-volatile organic compound
TCE	Trichloroethylene
TDS	Total dissolved solids
TER	Technology Evaluation Report
TOC	Total organic carbon
UCL	Upper confidence limit
VOC	Volatile organic compound

Conversions

	English (US)	Metric (SI)
Area:	1 ft^2	9.2903×10^{-2} m^2
Flow Rate:	1 gpm	2.2712×10^{-1} m^3/hr
	1 scfm	1.6957 std m^3/hr
	1 lb/hr	4.5359×10^{-1} kg/hr
Length:	1 ft	0.3048 m
	1 in	2.54 cm
Mass:	1 lb	4.5359×10^{-1} kg
Temperature:	1 °F	5/9 (°F + 459.67) K
Volume:	1 ft^3	2.8317×10^{-2} m^3
	1 gallon	3.7854×10^{-3} m^3
	1 std ft^3 of gas	2.8262×10^{-2} std m^3

°F = degrees Fahrenheit
cm = centimeter
ft = foot, ft^2 = square foot, ft^3 = cubic foot
gpm = gallon per minute
in = inch
K = Kelvin
kg = kilogram, kg/hr = kilogram per hour
lb = pound, lb/hr = pounds per hour
m = meter, m^2 = square meter, m^3 = cubic meter
m^3/hr = cubic meter per hour
scfm = standard cubic feet per minute
std = standard conditions of 15.0°C and 101.325 kilopascal absolute

Acknowledgements

This report was prepared under the direction and coordination of Ms. Norma Lewis and Mr. Gordon Evans, U.S. Environmental Protection Agency's (EPA) Superfund Innovative Technology Evaluation (SITE) Project Managers in the Risk Reduction Engineering Laboratory, Cincinnati, Ohio. Mr. Chuck Biagi of AWD Technologies and Mr. David Jensen of Lockheed Engineering and Sciences Company contributed greatly to this report. Many other individuals reviewed and provided constructive comments to improve this document. Lockheed Aeronautical Systems Company is greatly appreciated for allowing the use of its site and treatment facilities and its assistance and cooperation throughout the SITE demonstration.

Dr. Gary Welshans, Mr. Behzad Behtash, Mr. Kent Morey, and Ms. Barbara Sootkoos of PRC Environmental Management, Inc., prepared this report for EPA's SITE Program under Contract No. 68-CO-0047. Engineering-Science, Inc., performed the sampling and analytical activities for this SITE demonstration.

Section 1
Executive Summary

Introduction

The integrated AquaDetox®/SVE technology developed by AWD Technologies, Inc., was evaluated under the U.S. Environmental Protection Agency's (EPA) Superfund Innovative Technology Evaluation (SITE) Program. The first field-scale system has been remediating volatile organic compound (VOC) contamination at the Lockheed Aeronautical Systems Company (LASC) at the San Fernando Valley Superfund Site, Area I (Burbank/North Hollywood Well Field) in Burbank, California since September 1988 and was the subject of the SITE technology demonstration. The demonstration was performed over a 2-week period in September 1990.

The AWD technology simultaneously treats groundwater and soil-gas contaminated with VOCs, such as trichloroethylene (TCE) and tetrachloroethylene (PCE). This technology integrates two basic processes: (1) a high-efficiency, moderate vacuum stripping tower (tower pressure *no* less than 50 mm Hg) that uses low-pressure steam to treat contaminated groundwater and (2) a soil vapor extraction (SVE) system that removes contaminated soil-gas for subsequent treatment with granular activated carbon (GAC). Integrating the two technologies creates a closed-loop system, providing simultaneous remediation of contaminated groundwater and soil-gas with virtually no air emissions.

The AWD technology demonstration had the following primary objectives:

- Evaluate the ability of the AWD integrated AquaDetox®/SVE system to remove the VOCs present in the contaminated groundwater and soil-gas at the Lockheed site at AWD-specified operating parameters.
- Evaluate the performance of the AWD system and its percent removal efficiencies for VOCs under varying operating conditions.
- Monitor the compliance of the AWD system with regulatory discharge requirements.
- Develop capital and operating costs for the system.
- Identify specific operating and maintenance concerns that may affect the long-term reliability of the system.

This report presents the findings of the AWD technology demonstration. The results and discussions presented in this report can be used to evaluate possible implementation of the AWD technology at other Superfund or Resource Conservation and Recovery Act (RCRA) Corrective Action sites. A detailed description of the technology is presented in Section 2 of the report. AWD technology's performance, requirements (operation and maintenance, site conditions, and personnel), and its applicability are discussed in Section 3. Section 4 presents an economic analysis of the system.

Demonstration Results

The SITE demonstration consisted of 21 test runs under varying operating conditions. The operating parameters that were varied during the demonstration were: (1) groundwater flow rate, (2) steam flow rate, (3) AquaDetox® stripping tower pressure, and (4) GAC bed regeneration frequency. Influent and effluent groundwater and soil-gas samples were collected during each test run for subsequent analyses. Temperature, flow rate, tower pressure, and were also measured and recorded for each test run.

The groundwater and soil at the Lockheed site were contaminated with TCE and PCE. Concentrations in the influent groundwater samples collected during the demonstration typically ranged from 400 to 600 μg/L for TCE and 2,000 to 2,500 μg/L for PCE. Soil-gas samples from the demonstration had concentrations of approximately 10 parts per million (ppm) for TCE and 400 ppm for PCE. No other VOCs were detected in the groundwater or soil-gas at the site.

Groundwater removal efficiencies for total VOCs (TCE and PCE combined) ranged from 99.92 to 99.99 percent. The removal efficiencies were slightly higher for PCE than TCE. Soil-gas removal efficiencies ranged from 98.0 to 99.9 percent for total VOCs when the GAC beds were regenerated in 8-hour shifts as specified by AWD. As expected, removal efficiencies were lower (as low as 93.4 percent) when the GAC beds were regenerated less frequently.

Ninety-five percent upper confidence limit (UCL) values for effluent groundwater TCE and PCE concentrations were compared with the regulatory discharge requirement (5 μg/L for each compound) for all test runs. Although the operating conditions in some test runs were less than optimum, the effluent from all test runs met the regulatory discharge requirement.

Economics

An economic analysis was performed that examined 12 separate cost categories for a moderate vacuum **AquaDetox®/SVE** system. Three treatment flow rates were evaluated: 500, 1,000, and 3,000 gallons per minute (gpm). Based on the economic analysis, the capital costs for the 500-, 1,OOO-, and 3,000-gpm systems were calculated to be approximately $3.2, $4.3, and $6.0 million (1991$), respectively. The total annual operation and maintenance (O&M) costs are approximately $510,000, $820,000, and $2,000,000 (1991$) for the 500-, l,OOO-, and 3,000-gpm systems, respectively. Section 4 of this report details the capital and O&M costs and presents the assumptions used to arrive at these estimates.

Field Reliability

Only one major operating problem was encountered during the SITE demonstration. The system was inoperable for approximately 4 days because of a broken SVE blower. This was considered to be unusual as the system has been operating successfully for over 2 years at the Lockheed site. During this time period, the system has been operational for 93 percent of the time, with 7 percent down time due to scheduled or nonscheduled repairs.

In the past, the high alkalinity of the groundwater at the Lockheed site had caused scaling problems in parts of the treatment system. A sulfuric acid injection system has been installed at the Lockheed site to control the groundwater's pH and to eliminate the scaling problem.

Conclusions

Based on the analytical results and observations from the AWD SITE demonstration, the following conclusions were made about the technology's effectiveness and cost.

- The AWD technology can successfully treat groundwater and soil-gas contaminated with VOCS.
- The efficiencies ranged from 99.92 to 99.99 percent for removal of VOCs from contaminated groundwater. VOC removal efficiencies for soil-gas ranged from 98.0 to 99.9 percent when the GAC beds were regenerated according to the AWD-specified frequency (8-hour shifts). VOC removal efficiencies dropped to as low as 93.4 percent when the GAC beds were regenerated less frequently.
- The AWD technology produced effluent groundwater that complied with regulatory discharge requirements for TCE and PCE (5 μg/L for each compound) at the Lockheed site throughout the SITE demonstration. In addition, routine sampling by Lockheed has shown that the effluent groundwater has been in compliance with the regulatory requirements throughout the 2-year operation of the system.
- The GAC beds effectively removed VOCs from contaminated soil-gas even after 24 hours of continuous operation without steam regeneration. The SITE demonstration results indicate that the GAC beds at the Lockheed site may be oversized for the current soil-gas VOC concentrations.
- The **AquaDetox®** system proved highly effective in removing such as TCE and PCE (boiling

points up to about 120°C) from contaminated groundwater. The system should also be effective for less volatile organics (boiling points in excess of 200°C according to the developer). However, because higher boiling point organics were not present in the groundwater treated during the AWD SITE demonstration, the system's effectiveness in removing this type of contamination could not be evaluated. Water containing such organics should be subjected to a treatability study.

- The system's steam consumption dropped with decreasing tower pressures. During the demonstration, the system proved more efficient at lower operating tower pressures.

- The system has been operating successfully for over 2 years at the Lockheed site. During this time period, the system has been operational for 93 percent of the time, with 7 percent down time due to scheduled or nonscheduled repairs.

- The AWD system is estimated to cost approximately $3.2, $4.3, and $6.0 million (1991$), for the 500-, 1,000-, and 3,000-gpm systems, respectively. The total annual operation and maintenance (O&M) costs are approximately $510,000, $820,000, and $2,000,000 (1991$) for the 500-, 1,000-, and 3,000-gpm systems, respectively.

Section 2
Introduction

This section provides background information about the Superfund Innovative Technology Evaluation (SITE) Program, discusses the purpose of this Applications Analysis Report, and describes the AWD technology. A list of key contacts who can provide additional information is provided in Appendix A.

Purpose, History, and Goals of the SITE Program

In response to the Superfund Amendments and Reauthorization Act of 1986 (SARA), EPA's Office of Research and Development (ORD) and Office of Solid Waste and Emergency Response (OSWER) established the SITE Program to accelerate the development, demonstration, and use of new or innovative technologies to clean up hazardous waste sites across the country. The SITE Program consists of five component programs: (1) Demonstration Program; (2) Emerging Technologies Program; (3) Measurement and Monitoring Technologies Development Program; (4) Innovative Technologies Program; and (5) Technology Transfer Program.

The primary purpose of the SITE Program is to enhance the development of and to demonstrate innovative technologies applicable to hazardous waste sites, and thereby establish their commercial availability. Major goals of the SITE Program are to:

- Identify and remove impediments to the development and commercial use of alternative technologies.

- Demonstrate promising innovative technologies in order to establish reliable performance and cost information for site characterization and cleanup decision making.

- Develop procedures and policies that encourage the selection of available alternative treatment remedies at Superfund sites.

- Structure a development program that nurtures emerging technologies.

EPA recognizes that a number of forces inhibit the expanded use of alternative technologies at hazardous waste sites. One of the objectives of the program is to identify these impediments and remove them or design methods to promote the expanded use of alternative technologies.

Another objective of the SITE Program is to demonstrate and evaluate selected technologies. This is a significant ongoing effort involving ORD, OSWER, EPA Regions, and the private sector. The demonstration program serves to test field-ready technologies and provide Superfund decision makers with the information necessary to evaluate the use of these technologies for future cleanup actions.

Another aspect of the SITE Program includes developing procedures and policies that match available technologies with wastes, media, and sites for actual remediation.

The SITE Program also provides assistance in nurturing the development of emerging innovative technologies from the laboratory- or bench-scale to the pilot- or scale stage.

Technologies chosen for a SITE demonstration must be pilot- or full-scale applications, innovative, and offer some advantage over existing technologies. Mobile technologies are of particular interest.

Documentation of the SITE Demonstration Results

The results of each SITE demonstration are incorporated into two documents: the Technology Evaluation Report (TER) and the Applications Analysis Report (AAR). The TER provides a comprehensive description of the demonstration and its results. A likely audience for the TER is engineers responsible for performing a detailed evaluation of the technology for a specific site and waste situation. These technical evaluators seek to understand, in detail, the performance of the technology during the demonstration and the advantages, risks, and costs of the technology for the given application. This information may be used to develop specific plans to test and evaluate the demonstrated technology.

The AAR is intended for decision makers responsible for implementing specific remedial actions. The basic use of the AAR is to assist in determining whether the specific technology should be considered further as an option for a particular cleanup. The report discusses the advantages, disadvantages, and limitations of the technology. Costs of the technology for different applications are estimated based on available data for the operational system. The report discusses the factors, such as site and waste characteristics, that have a major impact on performance and cost. If the candidate technology appears to meet the needs of the site engineers, a more thorough analysis should be conducted based on the TER, the AAR, and information from remedial investigations for the specific site.

Purpose of the Applications Analysis Report

To encourage the general use of demonstrated technologies, EPA will evaluate the applicability of each technology in regards to certain sites and wastes, other than those already tested, and will study the likely costs of these applications. The results are presented through the AAR. These reports attempt to synthesize available information on the technology and draw reasonable conclusions as to its broad range applicability. The AAR is very useful to those considering the technology for Superfund cleanups and represents a critical step in the development and commercialization of the treatment technology.

Each SITE demonstration will evaluate the performance of a technology in treating a particular waste found at the demonstration site. To obtain data with broad applications, attempts will be made to select waste frequently found at other Superfund sites. In many cases, however, the waste at other sites will differ in some way from the waste tested. Thus, the successful demonstration of a technology at one site does not ensure that it will work equally well at other sites. Data obtained from the demonstration may have to be extrapolated to estimate the total operating range over which the technology performs satisfactorily. This extrapolation should be based upon both demonstration data and other information available about the technology.

The amount of available data for the evaluation of an innovative technology varies widely. Data may be limited to laboratory tests on synthetic wastes, *or* may include performance data on actual wastes treated at pilot- or field-scale treatment systems. In addition, there are limits to conclusions regarding Superfund applications that can be drawn from a single field demonstration. A successful field demonstration does not necessarily ensure that a technology will be widely applicable or fully developed to a commercial scale.

Technology Description

The AWD technology simultaneously treats groundwater and soil-gas contaminated with volatile organic compounds (VOC), such as trichloroethylene (TCE) and tetrachloroethylene (PCE). This technology integrates two processes: (1) **AquaDetox®**, a moderate vacuum steam stripping tower (tower pressure no less than 50 mm Hg) that treats contaminated groundwater and (2) a soil vapor extraction (SVE) system that removes contaminated soil-gas for subsequent treatment with granular activated carbon (GAC). The two technologies are integrated into a closed-loop system, providing simultaneous remediation of contaminated groundwater and soil-gas with no air emissions. The integrated **AquaDetox®/SVE** system is shown in Figure 2-l.

AquaDetox® is a high-efficiency, countercurrent stripping technology developed by the Dow Chemical Company. Stripping is commonly defined as a process that removes dissolved volatile compounds from water. A carrier gas, such as air or steam, is purged through the contaminated water, with the volatile components being transferred from the water into the gas phase. According to the developer, the **AquaDetox®** technology can be

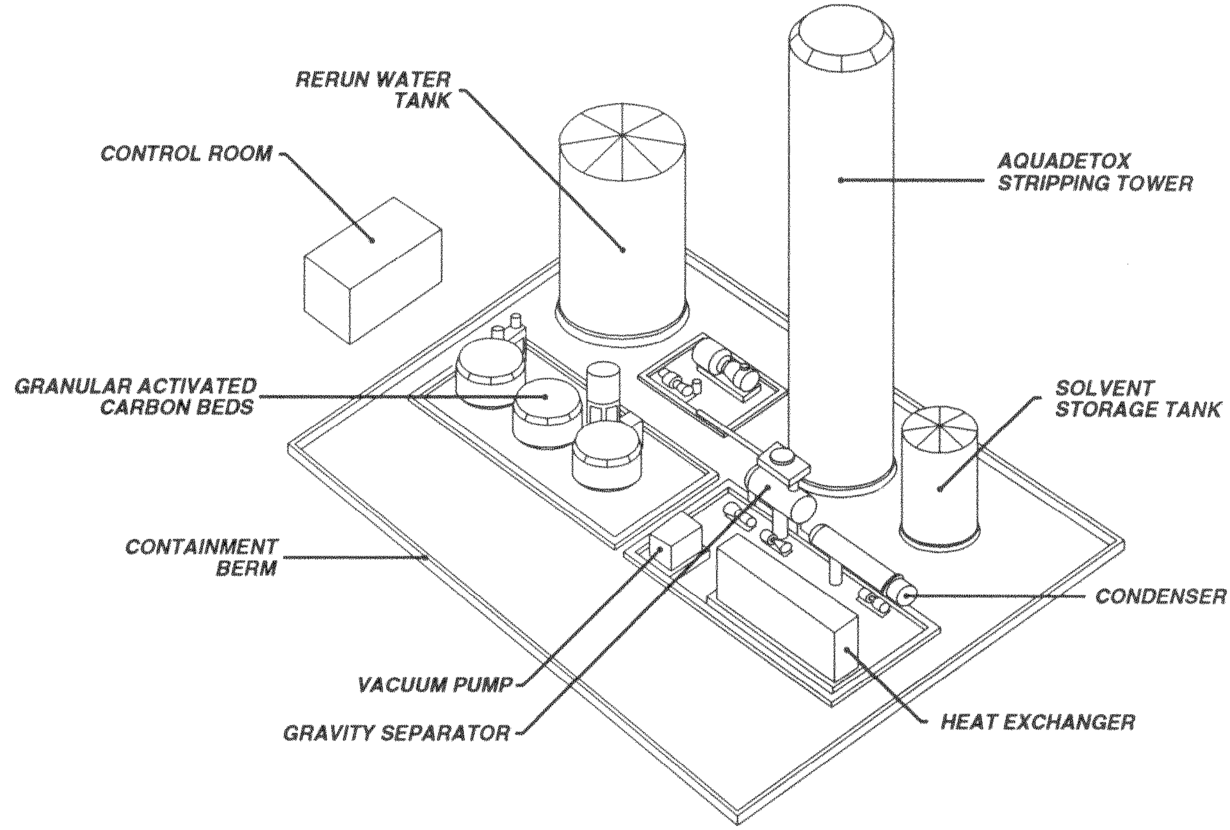

Figure 2-1. Isometric View of the AWD Integrated AquaDetox®/ SVE System.

used to remove a wide variety of volatile compounds and many compounds that are normally considered "nonstrippable" (i.e., those with boiling points in excess of 200°C). The application of **AquaDetox®** for the removal of compounds with boiling points greater than 200°C and the use of vacuum are patented by the Dow Chemical Company.

SVE is commonly used for the in-situ removal of VOCs from soil. A vacuum is applied to vadose zone extraction wells to induce air flow within the soil toward the wells. The air acts as a stripping medium that volatilizes the VOCs in the soil. Soil-gas from the extraction wells is typically treated in GAC beds before release to the atmosphere. Alternatively, the treated soil-gas is reinjected into the soil to control the direction of air flow in the soil.

The **AquaDetox®** and SVE systems are connected in a closed loop. Noncondensable .vapors from the **AquaDetox®** system are combined with vapors from the SVE compressor and treated using the GAC beds. The GAC beds are regenerated periodically using steam. This contaminated regeneration steam is then condensed and sent to the **AquaDetox®** tower for treatment.

A schematic diagram of the integrated **AquaDetox®/SVE** treatment system is shown in Figure 2-2. The demonstration system was designed to handle 1,200 gallons per minute (gpm) of groundwater and a maximum of 300 standard cubic feet per minute (scfm) of soil-gas. However, the system is normally operated at a rate of 900 gpm groundwater and 170 scfm soil-gas.

Groundwater Treatment System

The **AquaDetox®** stripping tower is a packed column approximately 9 feet in diameter and 60 feet in height. About 30 feet of the column are packed with plastic pall rings. The tower operates at a pressure of approximately 105 mm Hg. Low-pressure steam supplied at a rate of approximately 4,500 lb/hr maintains the tower at a temperature of 52°C.

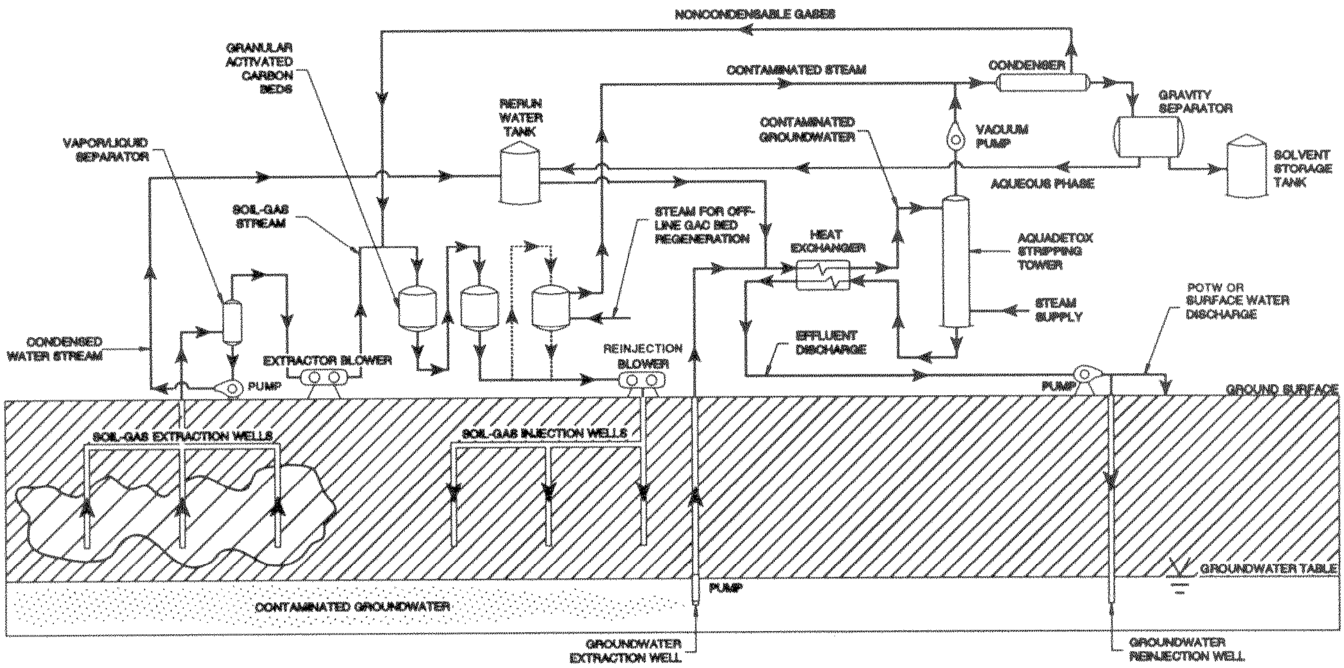

Figure 2-2. AWD Integrated AquaDetox®/ SVE System Schematic.

Contaminated groundwater is pumped to the treatment facility from an extraction well at an approximate depth of 150 to 170 feet. The extracted groundwater enters the facility at an approximate temperature of 18°C. This relatively cool groundwater is used to condense the stripping tower overheads and the steam used to regenerate the GAC beds. It is also fed to cross-flow heat exchanger where it cools the treated groundwaterexiting at the bottom of the tower from approximately **52°C** to 24°C. At the same time, the untreated groundwater is heated from a temperature of approximately 18°C to 48°C before entering the **AquaDetox®** stripping tower. Less steam is required to treat the groundwater at this higher inlet temperature.

As contaminated groundwater flows down the stripping tower, it is heated to the tower's operating temperature of 52°C by the injection of steam at the bottom of the tower. Under these conditions of temperature and reduced pressure, the VOCs are stripped from the groundwater and exit the top of the stripping tower along with the steam. The overhead stream flows to a water-cooled condenser where it is condensed and pumped to a gravity separator. The water for cooling the condenser is provided by diverting a portion of the cool untreated groundwater through the condenser and back to the main influent groundwater stream.

Total condensation of the overhead stream is not possible due to noncondensable gases present in the stream. The uncondensed vapor stream from the first condenser is sent to a secondary condenser where all but trace quantities of the VOCs are condensed and pumped to the gravity separator. The organic phase from the gravity separator is pumped to and stored in a solvent storage tank. The organics are periodically loaded from the solvent storage tank into a truck for off-site recycling. The aqueous phase from the gravity separator is pumped to and stored in the rerun water tank where it is recycled into the **AquaDetox®** stripping tower at a low flow rate. The vent from the secondary condenser contains all noncondensables and is sent to the GAC beds for treatment before discharge into the rejection wells of the **SVE** system.

Soil Vapor Extraction System

Soil vapor is removed through extraction well clusters at depths of approximately 150 feet and fed to a vapor-liquid separator where excessive moisture is separated from the vapor. The liquid collected in the vapor-liquid separator is pumped to the rerun water tank for treatment by the **AquaDetox®** stripping tower.

The vapor from the vapor-liquid separator is combined with the noncondensable vapors generated by the AquaDetox® process. This combined stream is treated by two GAC beds connected in series. The treated soil-gas coming off the bottom of the second GAC bed is reinjected into the soil at depths ranging from 50 to 150 feet through the vadose zone. The soil-gas then sweeps horizontally through the contaminated soil, picking up additional hydrocarbons, and is once again collected in the soil-gas extraction well system, where hydrocarbons are again removed.

A third GAC bed is regenerated while the other two GAC beds are on-line. The GAC beds are regenerated by injection of steam at the bottom of the beds. The steam removes the VOCs and exits through the top of the GAC beds. The contaminated steam is then condensed and sent to the AquaDetox® stripping tower for treatment. Once each 8 hours, the regenerated off-line bed is placed in service and a spent GAC bed is removed from service and regenerated.

Innovative Features of the Technology

Typical treatment options for VGC-contaminated groundwater include air or steam stripping, carbon adsorption, ultraviolet radiation/oxidation technologies, and biological treatment. VGC-contaminated soil may be treated by various technologies, including enhanced aeration, vacuum extraction followed by carbon adsorption, incineration, and biodegradation. An innovative feature of the AquaDetox®/SVE system is its ability to treat the contaminated groundwater and soil-gas simultaneously.

Steam stripping and SVE systems are widely used for remediation of contaminated water and soil. The technologies are well known. As such, neither technology can justifiably be labeled “innovative.” However, AWD Technologies’ integration of these two technologies produces a system that treats contaminated groundwater and soil simultaneously with no air emissions.

While the AquaDetox® system extracts and treats contaminated groundwater, an array of SVE wells removes contaminated soil-gas from the vadose zone. The soil-gas is treated by the carbon beds and reinjected into the ground to sweep through the soil and remove additional contamination. This integrated system combines the advantages of both technologies while eliminating many of the disadvantages that are normally associated with each technology.

Particularly, the integrated AquaDetox®/SVE system eliminates frequent GAC replacement and greatly simplifies the GAC regeneration process. Typically, GAC is used until it becomes saturated, at which time it is physically replaced with new or regenerated GAC. The costly physical removal and off-site regeneration of GAC is unnecessary with the AWD technology.

The process of acquiring an air permit is also simplified because the integrated AquaDetox®/SVE system was designed to operated with no air emissions. As air emission standards become stricter, AWD Technologies’ zero air emission advantage becomes increasingly important.

Section 3
Technology Applications Analysis

This section addresses the general applicability of the AWD integrated AquaDetox®/SVE technology to contaminated waste sites. The analysis is based primarily on the SITE demonstration results. Limited information about other applications of the technology is also presented. The developer's claims regarding the applicability and performance of the integrated AquaDetox®/SVE technology are included in Appendix B.

Technology Evaluation

The demonstration of the AWD integrated AquaDetox®/SVE technology was designed to achieve the following primary objectives:

- Evaluate the ability of the AWD integrated AquaDetox®/SVE system in removing the volatile organic compounds (VOC) present in the contaminated groundwater and soil-gas at the Lockheed site at AWD-specified operating parameters.
- Evaluate the performance of the AWD system and calculate its percent removal efficiencies for VOCs under varying operating conditions.
- Monitor the compliance of the AWD system with regulatory discharge requirements.
- Develop capital and operating costs for the system.
- Identify specific operating and maintenance concerns that may affect the long-term reliability of the system.

To achieve these objectives, a SITE Demonstration plan was developed (PRC, 1990) outlining a test plan consisting of 21 test runs. The demonstration was completed in September 1990. Analytical tests were performed on samples of untreated and treated waste materials collected during the demonstration. The results are summarized in Appendix C and are discussed more thoroughly in the Technology Evaluation Report. An overview of the demonstration and the effectiveness of the AWD technology are discussed below.

Site Demonstration Overview

The SITE demonstration was conducted at the Lockheed site in Burbank, California. The treatment system at this site is a full-size unit capable of treating 1,200 gallons per minute (gpm) of groundwater and 300 standard cubic feet per minute (scfm) of soil-gas. The system began operation in September 1988. The use of a full-size unit for the SITE demonstration made system modifications, such as the addition of sampling ports and flow meters more difficult or impossible to achieve. In addition, certain operating conditions were unattainable because of the site-specific design of the system.

There were, however, advantages to using a full-size system for the demonstration. A major advantage of demonstrating a full-size system is that the results achieved by the system at Lockheed are more likely to be duplicated by other systems at similar sites. In addition, demonstrating a full-size system eliminates scale-up considerations. Finally, the nature of operational problems encountered during this demonstration should be indicative of what to expect at other sites.

During the demonstration, the system treated groundwater and soil-gas contaminated with VOCs. The primary contaminants present at the Lockheed site were trichloroethylene (TCE) and tetrachloroethylene (PCE) in soil and groundwater. The effectiveness of the AWD technology was evaluated by analyzing the soil-gas and groundwater samples that were collected for each test run. The groundwater and recovered solvent samples were analyzed for VOCs using EPA SW-846 Methods 8010, 8015, and 8020. The soil-gas samples were analyzed for VOCs using NIOSH Methods 1003 and 1022. In addition, several groundwater samples were analyzed for polychlorinated biphenyls (PCB) and semi-volatile organic compounds (SVGC) using SW-846 Methods 8080 and 8270, respectively. Other groundwater analysis included alkalinity, hardness, pH, temperature, total organic carbon (TOC), and total dissolved solids (TDS).

Effectiveness of the AWD Technology

The analytical results indicate that the AWD technology effectively reduced the concentration of VOCs in the treated groundwater and soil-gas. Groundwater removal efficiencies of 99.92 percent or better were observed in all test runs for TCE and PCE. In addition, the effluent groundwater concentrations of TCE and PCE were below the regulatory discharge limit of 5 µg/L (each) for all the test runs. Soil-gas removal efficiencies ranged from 98.0 to 99.9 percent for total VOCs (TCE and PCE combined) when the granular activated carbon (GAC) beds were regenerated in 8-hour shifts as specified by AWD. As expected, removal efficiencies were lower (as low as 93.4 percent) when the GAC beds were regenerated less frequently. Reinjected soil-gas was not subject to regulatory requirements.

Factors Influencing Performance

Waste characteristics, operating conditions, maintenance requirements, and other factors influencing the performance of the AWD technology are discussed below.

Waste Characteristics

The AquaDetox®/SVE system at Lockheed was designed to handle influent groundwater VOC concentrations of approximately 12,000 µg/L and soil-gas VOC concentrations of approximately 6,000 parts per million (ppm). Significantly higher influent VOC concentrations may produce effluent groundwater that does not meet the regulatory discharge requirements; however, the operating conditions of the system can be modified to improve its overall removal efficiency at the expense of higher operating costs. The developer claims that systems can be designed to accommodate much higher influent VOC concentrations than those encountered at the Lockheed site. According to AWD Technologies, the design of a system is not significantly impacted until the intluent VOC concentrations exceed 200,000 µg/L.

Characteristics of Contaminated Groundwater

Characteristics of the organic contaminants also influence removal efficiencies. The AquaDetox® system is designed to treat organics with higher boiling points than is possible with more traditional designs such as nonvacuum air strippers. However, the boiling point and vapor pressure of the organic contaminants do influence the efficiency of the AWD technology. Generally, organics with lower boiling points and higher vapor pressures such as VOCs are more readily stripped by the AquaDetox® system. However, the system is not limited to VOCs. According to the developer, organics with boiling points in excess of 200°C can be successfully treated by the AWD system.

Hardness, pH, and alkalinity of the influent groundwater are also important characteristics. High alkalinity and hardness can cause scaling problems in various parts of the system. At the Lockheed site, the high alkalinity of the influent groundwater (alkalinity range of 250 to 340 mg/L, as $CaCO_3$) was causing scaling problems in the heat exchanger, reducing the heat transfer efficiencies and increasing steam consumption. A sulfuric acid injection system was employed at Lockheed to control the scaling problem.

Characteristics of Contaminated Soil

Low boiling points and high vapor pressures are also desirable characteristics for organic contamination in the soil. Organics with high vapor pressure, such as TCE and PCE, are more readily removed from the soil by the SVE system.

Physical characteristics of the contaminated soil must be evaluated to determine if SVE is a feasible solution. Grain size, moisture content, stratification, and air permeability are the most important properties in this regard. Significant differences are generally observed in the air conductivity of the various strata. A horizontally stratified soil is usually suitable for SVE. Its relatively impermeable strata limits the rate of vertical inflow from the ground surface and tends to extend the applied vacuum horizontally to useful distances from the point of application.

SVE is best suited for highly permeable soils with a large grain size and a low moisture content. However, for soils with even moderate permeability (permeability range of about 10^{-3} to 10^{-5} cm/sec), sufficient air flow for removal of contaminants is possible. However, the success of SVE in these soils may be more dependent on the presence of conductive strata such as sand or gravel. Typically, the soil-gas extraction rate should be approximately 100 to 1,000 scfm at an applied vacuum of 50 to 150 mm Hg.

There are few guidelines for optimal design, installation, and operation of SVE systems. Especially lacking are theoretical design equations that would define the limits of the technology. Consequently, it may be beneficial to install and operate a small-scale or partial system on a short-term basis to determine if a full-scale system should be installed. If a full-scale SVE system proves feasible, data collected from the installation and operation of a partial system can be used for designing a full-scale system.

Operating Parameters

Operating parameters can be varied during the operation to achieve desired treatment efficiencies. The operating parameters that were varied during the SITE demonstration were the groundwater flow rate, steam flow rate, stripping tower pressure, and the regeneration period of GAC beds. These are the basic operating parameters for the AWD AquaDetox®/SVE technology.

In general, lower tower pressures increase the efficiency of the AquaDetox® stripping tower, and reduce the required steam flow rate. Figure 3-1 shows the relationship between the stripping tower pressure and required steam flow rate. Because the groundwater flow rate was not constant for all test runs, the steam flow rate is reported per unit groundwater flow rate.

As shown on Figure 3-1, there is a direct relationship between the tower pressure and steam flow. During the SITE demonstration, approximately 20 percent of the steam consumption was used to strip contaminants, the other 80 percent was used to raise the incoming water to its boiling point of approximately 52°C at 105 mm Hg. As the stripping tower pressure was reduced, the operating tower temperature, corresponding to the boiling point of water, was also reduced. For example, at 75 mm Hg (Run 15), the tower temperature was lowered to 46°C. The amount of steam required to bring the temperature of the influent groundwater from 18°C to this lower tower temperature was significantly less.

Since approximately 80 percent of the steam is used for heating of the influent groundwater, a significant reduction in steam used for heating lowers the overall steam requirements substantially. Steam requirements for Runs 1 (105 mm Hg) and 8 (160 mm Hg) were 27 and 70 percent higher, respectively, than Run 15 performed at 75 mm Hg. Lower tower pressures also increase the ability to strip higher boiling point organics.

Operation at low stripping tower pressures are possible by using a larger vacuum pump, reducing the groundwater flow rates, or both. During the SITE demonstration, the lower tower pressures (75 to 95 mm Hg) could only be achieved when the groundwater flow rate was reduced from 900 to 600 gpm because the system was designed to operate at a pressure of 105 mm Hg. A system designed with a larger vacuum pump would allow operation at lower tower pressures without requiring a reduction in the groundwater flow rate, thereby reducing steam consumption and increasing the system's overall efficiency. However, larger vacuum pumps have higher capital costs and are more costly to operate.

Tower pressures in the 75 to 85 mm Hg range seemed most efficient; however, operation at these reduced tower pressures was only possible when the groundwater flow rates were also reduced. Replacing the existing vacuum pump with a larger system would allow higher groundwater flow rate operation at reduced stripping tower pressures and would improve the system's efficiency.

Maintenance Requirements

Regular maintenance by a field technician is required for successful operation of the AquaDetox®/SVE system. The system at Lockheed has operated successfully since September 1988. According to AWD Technologies, the system has been operational for 93 percent of the time, with 7 percent down time due to scheduled or nonscheduled repairs.

Routine maintenance for prevention of scaling should include inspection of groundwaterlines, heat exchangers and condensers, and the stripping tower. Particularly

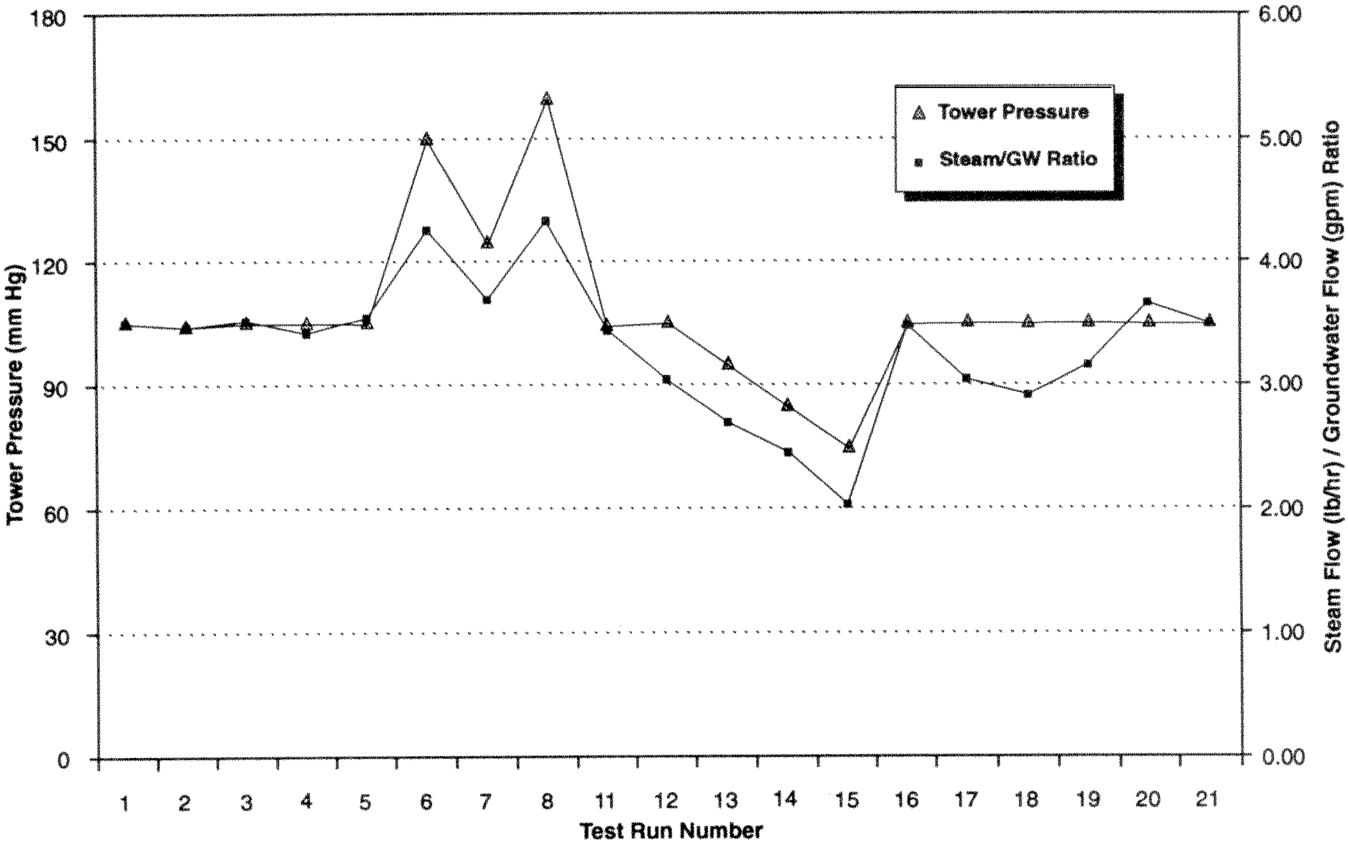

Figure 3-1. Tower Pressure vs. Steam / Groundwater Flow Rate Ratios for all Test Runs.

important are the heat exchangers and condensers where the operating efficiencies can be greatly reduced by excessive scaling. Antiscaling agents such as sulfuric acid minimize scaling. At the Lockheed site, sulfuric acid is routinely injected into the influent groundwater stream to control scaling.

To date, major equipment repairs at the Lockheed site have included rebuilding of a blower and replacing the seals for the water rerun pump. Generally, piping, valves, fittings, pump seals, blowers, and control valves should be routinely inspected and repaired as required.

In-line measurement instrumentation including resistor temperature detectors, differential pressure transmitters, turbine and magnetic flow meters for groundwater, and gas stream flow meters should be maintained regularly. Most of the measurement instruments at the Lockheed plant required no field calibration. However, if required by the manufacturer, calibration procedures outlined in the owner's manual should be followed for each instrument.

Site Factors

Site-specific factors have an impact on the application of the AWD technology. These factors should be considered before using this technology.

Space

The 1,000-gpm treatment system at the Lockheed site is laid out in a 4,000-square-foot area (52 feet by 75 feet). The equipment is placed on a concrete pad with a 2-foot spill containment berm surrounding the facility. A control room containing the computer equipment is located outside the containment area.

Utilities for the system at Lockheed, including steam and electricity, are supplied from existing services on or adjacent to Lockheed property. If these services are not readily available at another site, additional space for steam generating boilers and electrical systems will be required.

The number and placement of groundwater and soil-gas extraction and reinjection wells are also site-specific. The system at Lockheed has one groundwater extraction and one groundwater reinjection well. Soil-gas is extracted through seven extraction wells, in three clusters, and reinjected to the vadose zone through a series of five reinjection wells. The exact number and placement of wells required for any system will depend upon the system capacity, plume location, size, and movement for groundwater wells; and, soil conditions and contamination profile for the soil-gas wells.

Additional space is required for storage, parking, and site access for removal of recovered contaminants.

Climate

Climatic conditions can affect the AWD system and may require design modifications for extreme conditions. During the September 1990 SITE demonstration at the Lockheed site in Burbank, extremely hot conditions were encountered. Mid-day temperatures were in the high 90s to over 100°F range. Under these extreme conditions of heat and direct sunlight on the AquaDetox® tower, the normal operating pressure of 105 mm Hg (or lower) was unattainable. A larger capacity vacuum pump should be considered for systems that will be located in warmer climates.

Utilities

Steam is required for the operation of the AquaDetox® tower and regeneration of the GAC beds. The amount of steam required depends on the system's capacity, as well as the operating conditions. The AquaDetox®/SVE system at Lockheed required a steam flow rate of 3,800 pounds per hour (lbs/hr) at a groundwater flow rate of 900 gpm. Considerably less steam was used for regeneration of the GAC beds. GAC bed regeneration steam was supplied at a flow rate of approximately 340 lbs/hr. Existing steam plants on Lockheed property supplied the steam required for the system at the Lockheed site. Systems at other sites may require on-site steam generating boilers sized according to the system's overall capacity.

The treatment system at Lockheed requires an electrical source capable of supplying 88 kilowatts (kW). Electrical consumption depends on the system's capacity and operating conditions. If an on-site source is not readily available, additional provisions may be required.

Services and Supplies

A number of services and supplies are required for the AWD technology. Most of these services and supplies can be obtained locally. A telephone connection is required to contact emergency services and to provide normal communications.

Replacement parts and calibration equipment may be obtained locally or shipped from regional companies. Other supplies such as tools and drums can also be purchased locally.

A security fence may be necessary to protect the equipment at night and to prevent access to the site by unauthorized personnel. Also, the services of a hazardous waste recycling company are required for periodic removal of recovered contaminants from the site.

Materials Handling

Material handling for the AquaDetox®/SVE technology, including pretreatment requirements and residual handling, are discussed below.

Pretreatment Requirements

Due to the high alkalinity of the influent groundwater at the Lockheed site, antiscaling treatment of the influent groundwater is required. The principal disadvantage of scaling is the reduction in heat transfer efficiency of the cross exchanger, resulting in greater steam consumption. An antiscalant agent such as PT 110, which is an aqueous polyelectrolyte complex with microbiological control agents, may be added to the influent groundwater to control scaling. At the Lockheed site, however, persisting scaling problems required an alternative solution. To resolve the scaling problem at Lockheed a sulfuric acid injection system was installed to control pH and reduce scaling.

In addition, sites with high total dissolved solids (TDS) in the groundwater may require filtering of the influent stream. Groundwater with a high TDS content can reduce the stripping tower's efficiency.

Residual Handling

Three types of residuals are generated by the AquaDetox®/SVE system: (1) effluent groundwater; (2) recovered organics; and (3) spent GAC. The treated groundwater is disposed of off-site. Three off-site disposal options are available: (1) surface water discharge; (2) discharge to a publicly-owned treatment works (POTW); or (3) reinjection back into the aquifer. During the SITE demonstration, the treated groundwater was discharged to a storm sewer system. Currently, Lockheed is reinjecting the treated groundwater back into the aquifer using a groundwater reinjection well.

The recovered organics are stored in an on-site storage tank. Periodically, a licensed waste hauler removes the organics for recycling or off-site treatment depending on the nature of organics. The GAC at the Lockheed site has not been replaced since the system became operational in September 1988. It is estimated that GAC replacement will not be necessary until after at least 3 years of operation.

Personnel Requirements

The entire AquaDetox®/SVE system is controlled by a computer system housed inside a small control room adjacent to the process equipment. Although fully automatic operation of the system is possible using the computer control system, a field technician is needed to make control adjustments, check and maintain the equipment, make routine repairs, and collect groundwater samples.

At the Lockheed site, a full-time field technician maintained and operated the facility during the initial start-up period. After 6 months of operation, the field technician's time requirement was reduced to 24 hours per week. It is anticipated that the field technician will be needed for about 16 hours per week for future operation of the treatment facility.

The time requirements for a field technician are reduced by the computerized and highly automated control of the treatment system and the built-in safety features that automatically shut down the system if the system malfunctions or is not operating within pre-specified parameters. For example, if a pump fails or the stripping tower pressure exceeds an acceptable value determined by AWD Technologies, the control system will then automatically shut down the system. Alarm conditions are logged by the computer and an automatic telephone dialer will notify the field technician about the shut down.

The operating personnel are subject to Occupational Safety and Health Act (OSHA) regulations. Specific health and safety issues will vary depending on the type of contamination present at a site. Therefore, a site-specific Health and Safety Plan should be prepared. This plan should include the facility description, a list of chemicals of concern and their concentrations, health and safety zones, personnel protective clothing and equipment, contaminant monitoring procedures, hospital routes, and the personnel to contact in the event of an emergency.

Potential Community Exposures

Contaminant emissions from the AWD technology are minimal. The AquaDetox®/SVE system produces no air emissions; therefore, no major potential for on-site personnel or community exposure to airborne contaminants is anticipated. The SITE demonstration results also indicated that the AWD technology reduced the concentrations of TCE and PCE in the effluent groundwater to below the regulatory discharge requirements for these compounds. In case of system malfunction, all components of the system will shut off automatically, leaving no threat to the community.

Appropriate Waste and Site Conditions

The suitability of the AWD technology for a hazardous waste site depends on several factors that must be evaluated before selection of a site remediation method. The suitability of a site is determined through waste treatability studies and measurement of physical conditions at the site. An obvious requirement for any candidate site for the AWD technology is VOC contamination of both groundwater and soil, a relatively common occurrence. A thorough site assessment should include the following steps:

- Review previous studies of similar wastes.
- Determine conventional water quality parameters and specific contaminants present in the groundwater and soil at the site and perform treatability testing on wastes from the site.

- Identify potential pretreatment options to improve the waste treatment process.
- Assess site conditions affecting the treatment of waste and the disposal of the treated waste.
- Review health and safety requirements.

Regulatory Requirements

This subsection discusses the regulatory requirements for the **AquaDetox®/SVE** system as they relate to conducting a hazardous waste site remediation. A discussion of potential applicable or relevant and appropriate requirements (ARAR) for a given remedial action using the **AquaDetox®/SVE** process is provided in Table 3- 1.

Comprehensive Environmental Response, Compensation, and Liability Act

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980 authorizes the Federal government to respond to releases or potential releases of any hazardous substance into the environment, as well as to releases of pollutants or contaminants that may present an imminent or significant danger to public health and welfare or the environment.

The Superfund Amendments and Reauthorization Act of 1986 (SARA) amended CERCLA and directed EPA to:

- Use remedial alternatives that permanently and significantly reduce the volume, toxicity, or mobility of hazardous substances, pollutants, or contaminants.
- Select remedial actions that protect human health and the environment, are cost-effective, and involve permanent solutions and alternative treatment or resource recovery technologies to the maximum extent practicable.
- Avoid off-site transport and disposal of untreated hazardous substances or contaminated materials when practicable treatment technologies exist (Section 121 (b)).

As part of the requirements of CERCLA, EPA has prepared the National Contingency Plan (NCP) to address responses to releases of hazardous substances. The NCP (codified in 40 CFR Part 300) delineates the methods and criteria for determining the appropriate extent of removal and cleanup for hazardous substance contamination.

In general, there are two types of responses possible under CERCLA: removal actions and remedial actions. The **AquaDetox®/SVE** process can be part of either response type. However, if the process is used only for a removal action, it will be limited in the amount of time and money spent to implement the response. Superfund-financed removal actions cannot exceed 12 months in duration or $2 million in cost in most cases (Section 104(c) (1)).

Remedial actions are governed by CERCLA as amended by SARA. As stated above, these amendments promote remedies that permanently reduce the volume, toxicity, and mobility of hazardous substances, pollutants, or contaminants. Section 121 (c), of CERCLA as amended by SARA, requires EPA to review any remedial action in which hazardous substances, pollutants, or contaminants remain at the site.

ARARs dictate the degree of cleanup necessary at CERCLA sites. Requirements for identifying ARARs are codified in 40 CFR Section 300.400(g). On-site remedial actions must comply with Federal or more stringent state ARARs that are determined on a site by site basis.

No Federal, state, or local permits are required for on-site response actions conducted pursuant to CERCLA Section 104. Thus the process would be exempt from these permit requirements, if used as part of an "on-site" response action (40 CFR Section 300.400(e)).

Resource Conservation and Recovery Act

RCRA, an amendment to the Solid Waste Disposal Act, was passed in 1976 to address the problem of how to safely manage and dispose of municipal and industrial solid wastes. RCRA specifically addresses the identification and management of hazardous wastes. The Hazardous and Solid Waste Amendments of 1984 (HSWA) significantly expanded the scope and requirements of RCRA. RCRA regulations concerning hazardous waste identification and management are specified in 40 CFR Parts 124, 260-272. EPA- and

Table 3-1. Federal and State ARARs for the AquaDetox®/ SVE Process

Process Activity	ARAR	Description	Basis	Response
Waste identification (untreated soil-gas and groundwater)	RCRA 40 CFR Part 261 or state equivalent	Identifying and characterizing the waste	A requirement of RCRA prior to managing and handling the waste	Chemical and physical analysis must be performed as well as determining if the soil-gas or groundwater was contaminated with a listed hazardous waste
Extraction of soil-gas groundwater	RCRA 40 CFR Part 262 or state equivalent	Standards applicable to the generation of hazardous waste	If contaminated soil-gas or groundwater is determined to be a hazardous waste and is extracted for treatment, the requirements for a hazardous waste generator will be applicable	Obtain an EPA identification and number
Waste processing	RCRA 40 CFR Parts 264 and 265 or state equivalent	Standards applicable to the treatment of hazardous waste at permitted and interim status facilities	Treatment of hazardous waste must be conducted in a manner that meets the operating and monitoring requirements	Previous testing indicates that soil-gas and groundwater to be treated fs compatible with the AquaDetox®/SVE process. Equipment must be operated and maintained daily.
Transportation of recovered solvent for further reclamation	RCRA 40 CFR Part 262 or state equivalent	Manifest and labeling requirements prior to transporting	Solvents recovered from the treatment of a listed hazardous waste which require further reclamation must be managed as a hazardous waste	EPA must issue an identification number
	RCRA 40 CFR Part 263 or state equivalent	Transportation Standards	The recovered solvents must be transported as hazardous waste	A transporter licensed by EPA must be used to transport the hazardous waste according to EPA regulations
Discharging treated groundwater to storm drain or POTW	CWA 40 CFR Part 122 or state equivalent	Discharge Standards	Water discharged to a surface water body must meet NPDES permit standards and water discharged to a POTW must meet pretreatment standards	Meet NPDES permit standards or pretreatment standards
On-site monitoring and maintenance activities	OSHA 29 CFR Part 1910, Subpart I or state equivalent	Personnel Protection Standards	Personnel performing activities on hazardous waste sites must comply with OSHA requirements	Wear personal protective equipment such as Tyveks, rubber gloves, and eye guards

RCRA-authorized states implement and enforce RCRA and state regulations.

The key to determining whether RCRA regulations apply to the AquaDetox®/SVE process is whether the contaminated media is a hazardous waste. EPA defines hazardous waste in 40 CFR Part 261. It is unlikely that soil-gas will meet the statutory definition of a solid waste; however, EPA has no specific policy on this matter. If groundwater is contaminated with a listed hazardous waste and extracted, the groundwater must be treated as a hazardous waste.

If contaminated soil-gas or groundwater is determined to be a hazardous waste, and is extracted for treatment, storage, or disposal, the requirements for a hazardous waste generator will be applicable. Requirements for hazardous waste generators are specified in 40 CFR Part 262 and include obtaining an EPA identification number. If hazardous wastes are treated by the AquaDetox®/SVE process, the owner/operator of the treatment or disposal facility must obtain an EPA identification number and a RCRA permit from EPA- or RCRA-authorized state. RCRA requirements for permits are specified in 40 CFR Part 270. In addition to the permitting requirements, Part 270. In addition to the permitting requirements, owners and operators of facilities which treat hazardous waste must comply with 40 CFR Part 264.

Liquid organics recovered from the gravity separator that are transported off-site for further reclamation will be considered solid wastes and possibly considered hazardous wastes. If the liquid organics are determined to be hazardous wastes and must be stored on-site prior to treatment, other RCRA regulations may apply. These regulations may include complying with the use of a Uniform Hazardous Waste Manifest, if hazardous waste is transported off-site, complying with 90-day accumulation limits for facilities without hazardous waste storage permits (40 CFR Section 262.34), complying with 40 CFR Part 264 or 265, Subpart I, if hazardous wastes are stored in containers, and complying with 40 CFR Part 264 or 265, Subpart J, if hazardous wastes are stored in tanks.

Section 3020 of the RCRA statute allows the injection of groundwater into the aquifer from which it was withdrawn if the following requirements are met:

- The injection is a response taken under Section 104 or 106 of CERCLA, or part of a RCRA corrective action;
- The contaminated groundwater is treated to substantially reduce hazardous constituents prior to such injection; and
- The response action or corrective action will, upon completion, be sufficient to protect human health and the environment.

Air emissions from hazardous waste treatment, storage, or disposal operations are addressed in 40 CFR Part 264 and 265, Subparts AA and BB. The air emission standards are applicable to treatment, storage, or disposal units subject to the RCRA permitting requirements of 40 CFR Part 270 or hazardous waste recycling units that are otherwise subject to the permitting requirements of 40 CFR Part 270.

RCRA Corrective Action

RCRA regulations (Sections 264.100 - 264.101) require that a corrective action program be instituted as necessary to protect human health and the environment from all releases of hazardous waste or its constituents from any solid waste management unit. The corrective action program must be in compliance with groundwater protection standards and must begin within a reasonable amount of time after the groundwater protection standard has been exceeded. The contaminated water must be treated to the levels determined in the corrective action order. These levels can vary, depending on state and local requirements (e.g., National Pollutant Discharge Elimination System (NPDES), POTW, or maximum contaminant levels (MCL)).

Additionally, a groundwater monitoring program must be implemented to prove that the corrective action program has been effective. A corrective action must be completed during the compliance period to the extent necessary to ensure that the groundwater protection standard is met. However, if a corrective action is not completed within the compliance period, it must then continue for as long as necessary to achieve compliance with the groundwater protection standard.

Clean Water Act

The Clean Water Act (CWA), as amended by the Water Quality Act of 1987, describes standards and enforcement for discharges, including toxic and pretreatment effluent standards which are applied primarily to protect surface water quality. The CWA established the NPDES, which requires that (1) EPA publish water quality criteria for pollutants and (2) each state set water quality standards, using the EPA criteria, for every significant body of surface water within its borders. States then issue permits for discharges into these bodies of surface water.

NPDES requirements are specified in 40 CFR Part 122. Part 122 requires that contaminated water be treated to appropriate levels prior to discharging into a storm sewer or surface water body. If the AquaDetox®/SVE process is used as a RCRA corrective action and the treated water is discharged to a surface water body, a NPDES discharge permit would be required and pretreatment standards (if discharged to a POTW) would need to be identified.

Safe Drinking Water Act

The Safe Drinking Water Act (SDWA) of 1974, as most recently amended by the Safe Drinking Water Amendments of 1986, requires EPA to establish regulations to protect human health from contaminants in drinking water. The legislation authorized national drinking water standards and a joint Federal-state system for ensuring compliance with these standards.

The National Primary Drinking Water Standards are found in 40 CFR Parts 141 through 149. Wells used by operators of hazardous waste management facilities to dispose of hazardous waste into a formation within a quarter-mile of an underground source of drinking water will be classified as Class IV wells (Section 144.6 (d)). Operators considering using wells to reinject contaminated groundwater that has been treated and is being reinjected into the same formation from which it was drawn are not prohibited from constructing and operating Class IV wells if such injection is approved by EPA for cleanup of releases under CERCLA or RCRA corrective actions (Section 144.13 (c)).

Occupational Safety and Health Act

Superfund remedial actions and RCRA corrective actions must be performed in accordance with the OSHA requirements codified in 29 CFR Parts 1900 through 1926.

Although the **AquaDetox®/SVE** system requires limited personnel involvement once it is operating under desired conditions, technicians performing monitoring and sampling must **wear personal** protective equipment, such as rubber gloves and eye guards (Part 1910, Subpart I). Additional personal protective equipment may be needed when handling untreated groundwater. In addition, all personnel working on-site must have completed 40 hours of formal health and safety training in accordance with 29 CFR 1910.120(e). A medical surveillance program in accordance with 29 CFR 1910.120(f) should also be instituted.

State occupational safety and health requirements may be significantly stricter than Federal standards.

Section 4
Economic Analysis

Introduction

The costs associated with the AWD AquaDetox®/SVE system can be separated into 12 cost categories that reflect typical cleanup activities at Superfund and RCRA-corrective action sites. These categories include site preparation costs; permitting and regulatory costs; capital and equipment costs; startup and fixed costs; labor costs; supply and consumable costs; utility costs; costs for effluent disposal to a municipal system; residuals and waste shipping, handling, and transportation costs; analytical costs; equipment repair and replacement costs; and site demobilization costs. The estimated cost analysis presented in Table 4-l is based on the discussions of each cost category included in this section.

Basis of Economic Analysis

This economic analysis is based on the costs associated with the l,000-gallons per minute (gpm), moderate vacuum AquaDetox®/SVE system operating at the Lockheed site. The cost data for the 500- and 3,000-gpm systems were provided by Lockheed and AWD Technologies, or were extrapolated from the cost data for the l,000-gpm system. One-time costs as well as annual operation and maintenance (O&M) costs for these systems are presented in Table 4-l. These costs are order-of-magnitude (-30 to +50 percent) estimates, as defined by the American Association of Cost Engineers, and are based on 1991 costs.

This analysis assumes that the moderate vacuum system will be operated continuously, 24 hours a day, 7 days a week, for 1 year. During this l-year period, the moderate vacuum system would treat 0.26 billion gallons for a 500-gpm system; 0.52 billion gallons for a l,000-gpm system; and 1.6 billion gallons for a 3,000-gpm system. One year was chosen as the period of time for this analysis so that annual operating and maintenance costs could be determined. However, it should be noted that most groundwater remedial actions require a greater amount of time (e.g., 5 to 30 years).

The following two operating conditions were assumed: (1) vacuum pressure of 105 mm Hg within the steam stripping tower and (2) low pressure steam supplied at 4,500 lbs/hour to maintain the tower temperature at 52°C. Furthermore, this analysis assumes that the groundwater is contaminated only with VOCs, primarily TCE and PCE. The total VOC contaminant concentration is assumed to be approximately 12,000 µg/L, of which the concentrations of TCE and PCE combined comprise 11,000 µg/L. These contaminant levels are similar to those initially observed at the Lockheed site.

Site-Specific Factors Affecting Cost

Several major factors affecting the cost of the AWD system are highly site-specific. The site-specific factors most affecting the cost include the following: volume of contaminated groundwater and soil-gas to be treated; extent of contamination; site preparation requirements (i.e., length of access roads to be constructed and amount of regrading required for the treatment pad); extraction and wells required (i.e., number and type); and treatment goals.

The costs presented in this analysis are based on conditions found at the Lockheed site. Any assumptions made regarding site-specific costs are included in the discussions for each cost category. Site-specific costs for the AWD system are difficult to estimate since data from other remedial actions using the system are not available and, therefore, cannot be used to compare results and findings.

Table 4-1. Estimated Costs Associated with Moderate Vacuum AquaDetox®/ SVE Systems

Item	Estimated Costs (1991 $)		
	500-gpm	1,000-gpm	3,000-gpm
Site Preparation Costs[a]	650,000	930,000	1,350,000
Permitting and Regulatory Costs[a]	90,000	130,000	190,000
Capital Equipment Costs[a]	1,800,000	2,600,000	3,800,000
Startup and Fixed Costs[a]	110,000	121,000	161,000
Labor Costs[b]	71,000	71,000	110,000
Supply and Consumable Costs[b]	53,000	73,000	96,000
Utility Costs[b]	165,000	279,000	734,000
Effluent Disposal Costs (Municipal System)[b]	160,000	320,000	960,000
Residuals and Waste Shipping, Handling, and Transportation Costs[b]	0	0	0
Analytical Costs[b]	21,000	21,000	21,000
Equipment Repair and Replacement Costs[b]	41,000	58,000	76,000
Site Demobilization Costs[a]	500,000	500,000	500,000
Total One-Time Costs	3,150,000	4,281,000	6,001,000
Total Annual O&M Costs	511,000	822,000	1,997,000

[a] One-time costs.
[b] Annual operation and maintenance costs.

Cost Categories

The items and assumptions associated with each of the 12 cost categories in Table 4-l are discussed in the following subsections.

Site Preparation Costs

Site preparation costs can be divided into planning and surface preparation costs for the treatment system. Planning costs include the engineering, administrative, and construction management costs involved with system design and construction. Planning costs for the system are approximately 35 percent of capital equipment costs (10 percent for engineering, **15** percent for administrative, and 10 percent for construction management), or $630,000 for the 500-gpm system, $910,000 for the 1 ,000-gpm system, and $1,330,000 for the 3,000-gpm system.

Surface preparation costs can vary greatly depending on the type of site where the treatment operation takes place, the condition of the site, and the size of the treatment system. This analysis assumes that the treatment system and support facilities for each unit cover an approximately 10,000 square-foot area. Sites that require major clearing and regrading for the foundation will significantly increase site preparation costs. In addition, some sites may require the construction of access roads. This analysis assumes that surface preparation costs include temporary trailer rental, minor clearing of the site, and installation of emergency and safety equipment ($3,400); surface grading ($0.08/square foot); construction of a l-foot thick concrete foundation for the system ($0.57/squa.m foot); and **fencing** ($12.50/linear foot) (Means, 1990). Surface preparation costs, therefore, are approximately $20,000, including a 20 percent contingency.

Based on these assumptions, site preparation costs are approximately $650,000 for the 500-gpm system, $930,000 for the 1,000-gpm system, and $1,350,000 for the 3,000-gpm system.

Permitting and Regulatory Costs

Permitting and regulatory costs can vary depending on whether treatment is performed at a Superfund or RCRA-corrective action site. At Superfund sites, Section 121(d) of CERCLA as amended by SARA requires that remedial actions be consistent with any applicable or relevant and appropriate requirements (ARAR). For the **AquaDetox®/SVE** system, ARARs will affect the treatment goals set to meet discharge or reinjection requirements. At RCRA-corrective action sites, regulatory costs will increase since analytical protocols and monitoring reports need to be maintained during operation of the treatment system.

Permitting and regulatory costs will also vary depending on how the effluent is disposed. Permits are required for any discharges to publicly-owned treatment works (POTW) or any surface water bodies. Such permits may require additional effluent monitoring prior to discharge.

This analysis assumes that treatment is being conducted as part of a Superfund remedial action and that the effluent is discharged to a POTW. Permitting and regulatory costs are assumed to be approximately 5 percent of the capital equipment costs, or $90,000 for the 500-gpm system, $130,000 for the 1,000-gpm system, and $190,000 for the 3,000-gpm system.

Capital Equipment Costs

Capital equipment costs are one-time costs associated with purchasing and installing the treatment system on-site. These costs include purchasing and installing the following components of the system: an AquaDetox® vacuum stripping tower; a soil-gas vapor extraction/reinjection system; a three-bed granular activated carbon (GAC) unit; a control building; and, associated piping, pumps, blowers, heat exchanger, condensers, filters, separators, and aboveground tanks. In addition, the installation of one groundwater extraction well is included as part of capital costs. If an existing steam source is not available, cost of steam generating boilers need to be added to the capital costs.

This analysis assumes that for a 1,000-gpm moderate vacuum system, one groundwater extraction well and eight vapor extraction/reinjection wells will be installed at a total cost of $200,000. This cost is based on information provided by AWD and conditions at the Lockheed site, where (1) the contaminated aquifer is located 150 to 170 feet below ground surface and (2) all extraction and reinjection wells are located within 1,000 feet of the treatment plant. It should be noted that since the number of groundwater and vapor extraction/injection wells required for effective operation of the system is highly site-specific, costs for well installation will vary greatly from site-to-site. For the 500- and 3,000-gpm systems, well installation costs are estimated at $100,000 and $600,000, respectively.

Any contaminated soil removed during the installation of extraction and reinjection wells that is hazardous will need to be stored in compliance with RCRA and state requirements. Soil disposed of at a permitted landfill will have to be treated to meet Federal or state land disposal restriction requirements. Since hazardous waste disposal costs vary greatly depending on the type and level of contamination, as well as site location, this analysis assumes that hazardous soil is not generated during well installation.

Major components of the treatment system include the AquaDetox® tower and packing material, control room, computerized control system, GAC beds, and various process components including tanks, separators, condensers, pumps, piping, measurement instruments, and control valves. Capital equipment costs also include the initial utility connections required for the treatment system. For the SITE demonstration, only a new electrical connection was required; steam and electrical service were available from the Lockheed site. Utility connections can be either overhead or buried; however, buried utility connections typically require more design, planning, and construction. For this analysis, it is assumed that utility connections are overhead.

Based on these assumptions and on information provided by AWD, total capital costs are $1.8 million for the 500-gpm system; $2.6 million for the 1,000-gpm system; and $3.8 million for the 3,000-gpm system.

Startup and Fixed Costs

Startup and fixed costs include those required to mobilize equipment, perform an initial shakedown of the equipment, establish operating procedures, train operators, and perform health and safety monitoring. Mobilization and shakedown costs include transporting the unit to the site, performing an initial on-site checkout of the equipment, and evaluating the system's performance to determine the proper operating parameters for treatment. These costs are highly site-specific. For this analysis, mobilization and shakedown costs (including a 20 percent contingency) are assumed to be $100,000 for the 500-gpm system, $110,000 for the 1,000-gpm system, and $150,000 for the 3,000-gpm system.

To ensure safe, economical, and efficient operation of the system, a program to train operators is necessary. Training will include instruction on operating and maintaining the system as well as health and safety measures. This training will be given to one individual (i.e., a field technician) responsible for monitoring the system. This analysis assumes that AWD personnel will instruct the field technician for 1 week in the operation and maintenance of the system, and that the field technician will attend a 40-hour health and safety training course. Training costs for all systems are estimated to be approximately $11,000, including a 20 percent contingency.

Based on these assumptions, total startup and fixed costs for each system are assumed to be approximately $110,000 for the 500-gpm system, $121,000 for the 1,000-gpm system, and $161,000 for the 3,000-gpm system.

Labor Costs

Once the AWD AquaDetox®/SVE system is installed and shakedown is completed, the system requires very little labor for operation. One field technician will be needed to check and maintain the equipment, make routine repairs, and take water samples. Based on information provided by AWD and from case studies, this analysis assumes that for the 500- and 1,000-gpm systems, the technician would be needed for 16 hours a week, and for the 3,000-gpm system, the technician would be needed for 32 hours a week. These estimates do not include labor costs associated with major equipment repairs.

For the 500- and 1,000-gpm systems, the annual labor costs are estimated at $71,000. For the 3,000-gpm system, the annual labor costs are estimated at $110,000. The labor rates used in this analysis include indirect costs on labor such as benefits.

Supply and Consumable Costs

Supplies and consumables for the moderate vacuum systems include sulfuric acid to maintain pH and miscellaneous maintenance supplies such as oil and antiscalant chemicals. The volume of sulfuric acid used depends on the pH level and alkalinity of the contaminated water and the size of the system employed. The system at Lockheed requires about 70 gallons of 96 percent sulfuric acid solution per day at a cost of approximately $1 per gallon. The quantities of miscellaneous supplies used depend on the type and size of the system employed.

Based on current operating information provided by Lockheed, the annual costs for sulfuric acid and miscellaneous maintenance supplies are estimated at $53,000 for the 500-gpm system, $73,000 for the 1,000-gpm system, and $96,000 for the 3,000-gpm system.

Utility Costs

Utility costs include the amount of electricity needed to operate the AquaDetox®/SVE system. The AWD system runs on electricity from a local utility. Based on current operating information provided by Lockheed, which assumes a cost of $0.07/kWh, annual electrical costs are $42,000 for the 500-gpm system, $54,000 for the 1,000-gpm system, and $84,000 for the 3,000-gpm system.

Utility costs also include steam. Based on information provided by Lockheed, which assumes a cost of $5.70/1,000 pounds steam, the average annual costs for steam are assumed to be $123,000 for the 500-gpm system, $225,000 for the 1,000-gpm system, and $650,000 for the 3,000-gpm system.

For this analysis, utility costs do not include any costs associated with installing and maintaining a telephone line.

Total utility costs, therefore, are $165,000 for the 500-gpm system, $279,000 for the 1,000-gpm system, and $734,000 for the 3,000-gpm system.

Effluent Disposal Costs

Effluent disposal costs will vary significantly based on the type and amount of contaminants discharged. This analysis assumes that effluent will be discharged to a storm sewer system. The cost for effluent discharge to a storm sewer system at the Lockheed site is approximately $0.605 per 1,000 gallons. For the AquaDetox®/SVE system, effluent can also be reinjected into aquifers underlying the site, eliminating the effluent discharge costs; however, reinjection is also subject to stringent monitoring requirements.

This analysis also assumes that effluent monitoring will be performed routinely by a technician in accordance with requirements of the discharge permit. Costs for the technician to perform monitoring are included under the labor cost category, and costs for analyzing effluent samples are included in the analytical cost category. Based on the costs associated with discharging effluent at the Lockheed site, annual effluent disposal costs are approximately $160,000 for the 500-gpm system,

$320,000 for a 1,000-gpm system, and $960,000 for a 3,000-gpm system.

Residuals and Waste Shipping, Handling, and Transportation Costs

The residuals and waste associated with the AWD system include recovered organics, that can either be disposed of or recycled, and spent GAC, that may need replacement after approximately 3 years of operation. The costs or credits associated with removal of the recovered organics are highly site-specific. This analysis assumes that the organics disposal or recovery costs are negligible. In addition, GAC replacement costs are not included in this analysis since the exact required frequency of GAC replacement is yet to be determined.

Analytical Costs

Analytical costs include laboratory analyses, data reduction and tabulation, quality assurance/quality control (QA/QC), and reporting. This analysis assumes that one effluent sample will be collected and analyzed for organics each month. Monthly laboratory analyses are estimated at approximately $1,250, while data reduction and tabulation, QA/QC, and reporting are estimated at approximately $500 per month. Total annual analytical costs, therefore, are estimated at $21,000 per year.

Equipment Repair and Replacement Costs

Equipment parts that may require repair and replacement include motors, seals, gauges, regulators, gaskets, filters, and the GAC beds. Based on information provided by AWD, the annual costs for equipment repair and replacement are estimated at $41,000 for the 500-gpm system, $58,000 for the 1,000-gpm system, and $76,000 for the 3,000-gpm system. This corresponds to approximately 2 percent of capital costs for each system.

Site Demobilization Costs

Site demobilization will include operation shutdown, site cleanup and restoration, permanent storage costs, and site security. Site demobilization costs will vary depending on whether the treatment operation occurs at a RCRA-corrective action site or a Superfund site. Demobilization at a RCRA-corrective action site requires detailed closure and post-closure plans and permits. Demobilization at a Superfund site will not require extensive post-closure care; for example, 30-year monitoring is not required.

This analysis assumes that site demobilization costs include decommissioning the equipment and transporting it off-site. Costs for preparing closure plans and conducting post-closure monitoring are not included. In addition, this analysis assumes that the equipment has no salvage value. According to AWD Technologies, site demobilization costs do not vary significantly for systems with capacities in the 500- to 3,000-gpm range and are assumed to be $500,000 for each system.

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Appendix A
Key Contacts for the SITE Demonstration

Appendix A Contents

Appendix A
Key Contacts for the SITE Demonstration

Additional information on the AWD technology, the demonstration site, and the SITE Program can be obtained from the following sources.

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Appendix B
Vendor's Claims for the Technology

Appendix B Contents

Tables

Appendix B
Vendor's Claims for the Technology

Note: This appendix to EPA's Applications Analysis Report was prepared by AWD Technologies. Claims and interpretations of results in this appendix are those made by the vendor and are not necessarily substantiated by test or cost data. Many of AWD's claims regarding performance can be compared to the available test data in Appendix C.

Introduction

The Lockheed Aeronautical Systems Company (LASC) has over 200 acres of aircraft manufacturing facilities located in Burbank, California. Among the famous aircraft that have been assembled at this facility are the P-38 Lightning, the F-104 Stat-fighter, the U-2, and the L-1011.

In late 1987, solvent-contaminated soil and groundwater were identified near Building 175. As a result, the Los Angeles Regional Water Quality Control Board (RWQCB) issued a Cleanup and Abatement order requiring soil and groundwater remediation to commence by August 1, 1988, and October 15, 1988, respectively.

LASC selected AWD Technologies, Inc. (AWD) to design, install, and operate a treatment facility to meet the requirements of the RWQCB. AWD is a wholly owned subsidiary of The Dow Chemical Company. AWD provides a comprehensive range of services for remediation of contaminated soil and groundwater and can draw upon the specialized resources and expertise of its parent company.

The Technologies

Two existing technologies were integrated in an innovative way: **AquaDetox®,** a low-pressure steam stripping technology developed by Dow Chemical to extract volatile organic compounds (VOC) from the groundwater, and Soil Vapor Extraction (SVE) for the treatment of the VOCs in the vadose zone. The following paragraphs describe the unique features of these technologies. Their integration will be described in a subsequent section.

AquaDetox®

Over the past several years, an effort has been under way to improve the efficiency of air stripping in removing contaminants from groundwater. This work has led to the development of the **AquaDetox®** technology, which surpasses more conventional approaches to air stripping in terms of removal efficiency. In most cases, **AquaDetox®** can reduce contaminants in groundwater to below maximum contaminant levels (MCL) without liquid-phase carbon bed treatment. Moderate vacuum and deep vacuum **AquaDetox®** steam stripping go even further, allowing the near total recovery of contaminants for possible recycling.

AquaDetox® technology can be used to remove a wide variety of volatile compounds, and many compounds that are normally considered "nonstrippable" (i.e., those with boiling points in excess of 200°C). The application of **AquaDetox®** for the removal of compounds with boiling points greater than 200°C and the use of vacuum are patented by the Dow Chemical Company.

Stripping is commonly defined as a process to remove dissolved volatile compounds from water. A carrier gas, such as air or steam, is purged through the contaminated water, with the volatile components being transferred from the water into the gas phase. While the physical principles involved are straightforward, the practice of stripping has undergone considerable development since the early

Dow's effort has focused on:

- Development of the proper theoretical relationships that provided a clear understanding of the stripping process.
- Application of these relationships, along with the correct hardware, to attain higher levels of contaminant removal than previously possible.
- Development of the proper scale-up parameters to go from pilot units handling less than 1 gallon per minute (gpm) to production units handling over 3000 gpm.
- Development of the conditions under which compounds with very high boiling points (e.g., 200°C) can be stripped from water.
- Compilation of a vapor-liquid equilibrium data base with special emphasis on EPA priority pollutants.

The effort necessary to address these criteria has been carried out by the Separations Section of the Applied Science and Technology Department of Dow. The research and development has been under the direction of Dr. Lanny Robbins.

By the early 1980s, the result of this effort was the **AquaDetox®** process, an innovative technology for the high efficiency stripping of organic contaminants from water.

AquaDetox® is capable of effectively stripping over 90 of the 110 volatile compounds listed in CFR 40, July 1, 1986, by the EPA (see Table B-l). The ability of **AquaDetox®** to efficiently attain low levels of contamination in the effluent represents a major breakthrough. Conventional strippers will normally achieve only 95 to 98 percent removal of the contamination, whereas **AquaDetox®** can achieve up to 99.99 percent.

Another major concern raised regarding conventional stripping systems is that they simply transfer contaminants from the water to the air. The contaminated air is usually treated over carbon beds, but can still release significant amounts of contaminants to the atmosphere. The **AquaDetox®** steam stripper (moderate or deep vacuum) condenses the contaminated steam to form a multi-phase liquid from which the liquid phase contaminant can be decanted for possible recycling. Only a small stream of noncondensable gases is emitted following carbon treatment.

There are three versions of the basic **AquaDetox®** technology:

- Air Stripping **AquaDetox®**.
- Moderate Vacuum **AquaDetox®** (requires source of steam).
- Deep Vacuum **AquaDetox®** (does not require source of steam).

Typical schematic flow diagrams for each of the types of **AquaDetox®** technology are included in the paper by Street, Robbins, and Clark.

Soil Vapor Extraction

Soil vapor extraction (SVE) is a technology commonly applied for the in-situ removal of VOCs from soil. A vacuum is applied to vadose zone extraction wells to induce air flows within the soil toward the wells. The air acts as a stripping medium which volatilizes the VOCs in the soil. Soil-gas from the extraction wells is typically treated in carbon beds before release to the atmosphere. Alternatively, the treated soil-gas is reinjected in the soil to control the direction of air flow in the soil.

Integrated System

The integrated system consists of two basic processes: an **AquaDetox®** vacuum stripping tower using low-pressure steam and a soil-gas vapor extraction/reinjection process. The system removes VOCs from the groundwater and soil with no gaseous emissions to the atmosphere.

Integrating the two technologies creates a unique system. While the **AquaDetox®** system extracts and treats contaminated groundwater, an array of SVE wells removes contaminated soil-gas from the vadose zone. The soil-gas is treated by the carbon beds and reinjected into the ground to sweep through the soil and remove additional contamination.

The **AquaDetox®** and SVE systems share a granulated activated carbon (GAC) unit. When one of

Table B-1. Strippable EPA-Designated Priority Pollutants

Volatiles

acrolein
acrylonitrile
benzene
bromoform
carbon tetrachloride
chlorobenzene
chlorodibromomethane
chloroethane
2-chloroethylvinyl ether
chloroform
dichlorobromomethane
1,1-dichloroethane
1,2-dichloroethane
1,1-dichloroethylene
1,2-dichloropropane
1,3-dichloropropylene
methyl bromide
methyl chloride
methylene chloride
1,1,2,2-tetrachloroethane
tetrachloroethylene
toluene
1,2-trans-dichloroethylene
1,1,1-trichloroethane
1,1,2-trichloroethane
trichloroethylene
vinyl chloride

Acid Compounds

2-chlorophenol
2,4-dichlorophenol
2,4-dimethylphenol
p-chloro-m-cresol
pentachlorophenol
2,4,6-trichlorophenol

Base/Neutral

acenaphthene
acenaphthylene
anthracene
benzidine
benzo(a)anthracene
benzo(a)pyrene
3,4-benzofluoranthene
benzo(ghi)perylene
benzo(k)fluoranthene
bis(2-chloroethoxy)methane
bis(2-chloroethyl)ether
bis(2-chloroisopropyl)ether
bis(2-ethylhexyl)phthalate
4-bromophenyl phenyl ether
butylbenzyl phthalate
2-chloronaphthalene
4-chlorophenyl phenyl ether
chrysene
1,2-dichlorobenzene
1,3-dichlorobenzene
1,4-dichlorobenzene
3,3'-dichlorobenzidine[a]
di-n-butyl phthalate
2,4-dinitrotoluene
2,6-dinitrotoluene
di-n-octyl phthalate
1,2-diphenylhydrazine[a] (as azobenzene)
fluroanthene
fluorene
hexachlorobenzene
hexachlorobutadiene
hexachlorocyclopentadiene
hexachloroethane
indeno(1,2,3-cd)pyrene[a]
isophorone
naphthalene
nitrobenzene
N-nitrosodimethylamine[a]
N-nitrosodi-n-propylamine[a]
N-nitrosodiphenylamine[a]
phenanthrene
pyrene
1,2,4-trichlorobenzene

Pesticides

aldrin
alpha-BHC[a]
beta-BHC[a]
delta-BHC[a]
chlordane
4,4'-DDT
4,4'-DDE
4,4'-DDD
dieldrin
alpha-endosulfan[a]
beta-endosulfan[a]
endosulfan sulfate[a]
endrin aldehyde[a]
heptachlor
heptachlor epoxide
PCB-1242[a]
PCB-1254[a]
PCB-1221[a]
PCB-1232[a]
PCB-1248[a]
PCB-1260[a]
PCB-1016[a]
toxaphene

[a] Needs further pilot study to determine treatability

the GAC beds is regenerated, the steam and organic vapors are condensed in the secondary condenser of the **Aquadetox®** System. Condensed organics are pumped to a storage tank for recycle, water condensate is pumped to the recycle tank for further treatment by the **AquaDetox®** process, and noncondensables are transferred to the active GAC bed.

The integrated system was given a patent on July 11, 1989.

System Advantages

The advantages of the **AquaDetox®/SVE** system are:

- The **AquaDetox®/SVE** integrated system when utilized as described in this appendix results in zero air emissions.

- Can be utilized with very high concentrations of **VOCs** in both the groundwater and soil vapor. Concentrations of VOCs in the groundwater in excess of **200,000 µg/L** and 12,000 parts per million (ppm) in the soil vapor can be handled by the **AquaDetox®/SVE** integrated system.

- The sizing of an **AquaDetox®** steam stripping system, for a particular groundwater flow rate, is not significantly impacted by VOC concentration up to approximately 200,000 **µg/L.**

- Greatly reduced usage of GAC. At the Lockheed site the GAC beds have not been replaced since the start of operation in September 1988.
- Recovery of the organic solvent as a liquid phase. This recovered solvent can be disposed of through a solvent recycler.

The Project

On February 1, 1988, **LASC** awarded AWD a contract for pilot-testing, design, and installation of an integrated 1200-gpm groundwater treatment plant and a 300-standard cubic feet per minute (scfm) SVE system. Fast-track project techniques were used, and 7-l/2 months later all systems of the $4 million project were operational.

Groundwater Treatment Facility

The groundwater treatment technology at the Lockheed site is the moderate vacuum steam stripper **AquaDetox®** system.

Contaminated groundwater is fed from extraction wells to a cross exchanger, where it is heated by the treated water. The heated water then enters the top of the stripping column (9-feet diameter by 60 feet tall) and flows down the column, contacting the rising vapor flow generated by the introduction of steam to the bottom of the column. Under a pressure of 100 mm Hg (absolute), the contaminants are stripped from the liquid into the vapor stream, which exits from the top of the column. The treated water leaves the bottom of the column. The treated water passes through a heat exchanger, where it is cooled and the contaminated feedwater is heated. The water exiting the treatment facility is thereby 9 to **10°F** higher than the incoming groundwater.

The overhead vapors flow to a water-cooled condenser, where the water vapor is condensed and recycled back to the contaminated feedwater. The water for cooling the condenser is provided by diverting a portion of the cool feed stream through the condenser and back to the main feed stream. Total condensation of the overhead vapors is not possible due to noncondensable gases from "vacuum leaks" and dissolved gas contained in the contaminated groundwater. These noncondensable vapors, carrying some water, inert gases, and VOCs, enter a vacuum pump where they are compressed to atmospheric pressure. Cooling of this compressed vapor stream results in condensation of water and VOCs.

The water phase is recycled to the contaminated feedwater and the organic solvent phase is withdrawn for reclamation by a contract recycler. The coolant for this secondary condenser is supplied from the feedwater as is done for the first condensing unit.

The vent stream from the secondary condenser contains the noncondensables and an equilibrium quantity of VOCs. This stream is passed through vapor-phase GAC prior to discharge into the re-injection wells of the SVE system.

Soil Vapor Extraction System

Soil vapor extraction (SVE) is being used at the Lockheed site for remediation of contaminated soil because of the relatively volatile character of the reported contaminants, depth to groundwater in the range of approximately 150 to 170 feet, and the predominantly coarse-grained nature of subsurface soils.

The design of the SVE system focused on the distribution of the wells to produce an effective and nondisruptive pneumatic flow regime. "Effectiveness" of SVE was judged to depend on establishing radially inward flow (toward an extraction well) throughout the areas of probable soil contamination; "nondisruptive pneumatic flow regime" refers to injection well placement such that (1) fugitive atmospheric emissions are not created, and (2) soil-gas within the areas of probable soil contamination is not displaced from the zone of extraction well influence.

Extraction wells connected to a common header feed up to 300 scfm of contaminated soil-gas to the system for processing and decontamination via carbon adsorption. Liquids collected in the SVE scrubber sump are pumped to the water recycle tank for processing through the **AquaDetox®** tower. Vapors are exhausted to the GAC beds for hydrocarbon removal prior to reinjection.

Three GAC beds remove chlorinated hydrocarbons from SVE system extraction well soil-gas, along with vent gases from the **AquaDetox®** system. The GAC beds are operated alternately, with two beds on-line in series while the remaining unit is being regenerated. Once each 8 hours, the regenerated off-line bed is placed in service and the spent carbon bed is removed from service and regenerated. Steam is used to strip chlorinated hydrocarbons from the GAC units. The vapors from this regeneration process are condensed and processed in the **AquaDetox®** separator.

Treated soil-gas is reinjected into the ground at depths ranging from 50 to 150 feet through the vadose zone. The soil-gas then sweeps horizontally through the contaminated soil, picking up additional hydrocarbons, and is once again collected in the soil-gas extraction well system, where hydrocarbons are again removed.

System Operation

The groundwater treatment plant operates at an average flow rate of 1,000 gpm and the SVE at 170 scfm. The contaminants treated are listed in Table B-2. Initially, total VOC concentrations were 12,000 µg/L in the groundwater and 6,000 ppm in the soil-gas. After the integrated system had been operating several months, these concentrations had dropped to 5,000 µg/L and 450 ppm, respectively. At these lower levels, the **AquaDetox®/SVE** facility removes 60 pounds per day of PCE/TCE from the groundwater and 45 pounds per day from the soil-gas.

Table B-2 lists the major contaminants in the groundwater feed to the treatment plant. Effluent analyses show that all contaminants have been reduced to below the analytical detection level. This equates to a removal efficiency in excess of 99.99 percent. The soil-gas treatment by two of three 3,500-pound carbon beds removes VOCs to below 2 ppm before the air is reinjected in the ground. This equates to a removal efficiency of better than 99 percent.

While the treatment plant has operated consistently at average design flow rates (95 percent availability factor) and has produced water effluents at nondetectable VOC concentrations, it has not been devoid of typical start-up problems and one operational problem. The start-up problems were typically failures of instrumentation and control software bugs, which have since been resolved. A more persistent problem, however, has been caused by the high alkalinity of the groundwater and resulting calcium carbonate scaling in parts of the treatment plant.

Solubility of the calcium carbonate in the groundwater is reduced in two ways as the water is processed through the **AquaDetox®** system. First, the water is heated and, second, carbon dioxide is removed during the stripping process in the column, thereby increasing the pH. The principal disadvantage of scaling is the reduction in heat transfer efficiency of the cross exchanger, resulting in greater steam consumption. Initially, an antiscalant was injected into the feed water but could not totally halt the scaling due to the subsequent removal of carbon dioxide and concomitant pH increase. Periodically, the heat exchanger was acidified to maintain its heat transfer properties.

To resolve the scaling problem a sulfuric acid injection system was installed to control pH and eliminate scaling. The costs associated with the addition of sulfuric acid will be offset by: (1) the savings resulting from eliminating antiscalant injection; (2) the savings associated with the elimination of phosphoric acid used to periodically clean the heat exchanger; and (3) lower average steam consumption due to improved heat exchanger efficiency. Less than 20 percent of the steam consumption in the **AquaDetox®** facility is needed to strip contaminants, the other 80 percent is needed to raise the incoming water to its boiling point of 120°F at 100 mm Hg. The cross exchanger helps reduce this steam requirement by using heat from the effluent water. This is a highly energy-efficient and cost-effective approach, and future systems will have even larger heat exchangers.

Operating Costs

Annual operating costs for the **AquaDetox®/SVE** plant at LASC are:

> **Labor**: One individual was initially assigned full-time for the maintenance and operation of the facility, but after the first 6 months of operation, his time was reduced to 3 days per week. At the start of the third year of operation, 16 hours per week have been scheduled. Current labor costs are about $5,900 per month.
>
> Steam: Steam, which is presently provided by ann existing Lockheed boiler, is costed at $5.70 per 1,000 pounds. At a flow rate of 1,000 gpm, the steam consumption is 3,500 lb/hr before calcium carbonate scaling shows its effect on the cross exchanger efficiency. An additional 340 lb/hr of steam (equivalent continuous average) is used to regenerate the carbon beds. This results in a total

Table B-2. Integrated System at Lockheed-Burbank Design Criteria and Performance Results

AquaDetox®

Design Contaminants	Design Feed Water Concentration (μg/L)	Actual (11/88) Influent Concentration (μg/L)	Design Effluent Concentration (μg/L)	Actual Effluent Concentration (μg/L)
Trichloroethylene	3300.0	2200	4.5	<1
Toluene	180.0	<100	9.5	<1
Tetrachloroethylene	7650.0	11,000	3.5	<1
Trans-1,2-dichloroethylene	19.5	<100	15.0	<1
Chloroform	30.0	<100	N/A	<1
1,1-dichloroethane	18.0	<100	5.5	<1
1,2-dichloroethane	4.5	<100	0.8	<1
Carbon tetrachloride	7.5	<100	N/A	<1
Benzene	30.0	<100	0.65	<1
1,1,2-trichloroethane	34.5	<100	N/A	<1
Ethylbenzene	255.0	<100	N/A	<1

Soil Vapor Extraction

Contaminants	Actual (9/89) Extraction Soil-Gas (ppb)	Actual (9/89) Reinjection Soil-Gas (ppb)
Total Hydrocarbons	450,000	2,000
Tetrachloroethylene	420,000	365
Trichloroethylene	8,000	60

N/A Not applicable

monthly steam consumption using 3,840 lb/hr at a cost of $15,700.

Chemicals: Sulfuric acid is currently added at a rate to maintain the pH at 8.5. The current usage rate results in a monthly cost of $1,400.

Power: The power requirement to operate the treatment plant is 88 kW. At a cost of $0.07 per kWh, this represents a monthly cost of $4,200. This does not include the power consumption for the groundwater extraction well.

Supplies: Miscellaneous supplies such as oil, replacement gauges, pump seals, spare parts, etc. cost about $3,500 per month.

Based on the above breakdown, monthly operating costs average $30,700, or $.7 1 per 1,000 gallons. Further reductions are anticipated with time, and savings in steam costs can further be accomplished by installing larger cross exchangers. Scaling potential can also be reduced by the installation of a larger vacuum system which will allow a lower operating temperature.

References

Gary Street, Lanny Robbins, and James Clark, "**AquaDetox®** Stripping System for Groundwater Remediation," presented at HazMat Central 1989, Chicago, Illinois.

"Soil and Groundwater Remediation System" - US Patent 4,846,934 issued July 11, 1989.

Appendix C
SITE Demonstration Results

Appendix C Contents

Figures

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Appendix C
SITE Demonstration Results

Introduction

Appendix C presents a brief history of the Lockheed site and summaries of the AWD SITE demonstration results.

In January 1989, EPA solicited proposals from technology developers to demonstrate innovative technologies at Superfund sites under the SITE program. In response, AWD Technologies submitted a proposal for its integrated **AquaDetox®/SVE** technology. This technology is currently being used for remediating contamination at the Lockheed Aeronautical Systems Company (LASC) at the San Fernando Superfund Site, Area I (Burbank/North Hollywood Well Field) in Burbank, California. Figure C-l includes a map of the North Hollywood Well Field and shows the location of the Lockheed site. The Lockheed site and the AWD treatment facility are shown on Figure C-2. Through a cooperative effort between EPA's Office of Research and Development (ORD), EPA's Office of Solid Waste and Emergency Response (OSWER), EPA Region IX, AWD Technologies, and LASC, the technology was demonstrated under the SITE program at the Lockheed site in September 1990.

Site Characteristics

Groundwater contamination in the San Fernando Valley Groundwater Basin (SFVGB) wells was first discovered in 1980. Los Angeles Department of Water and Power's (LADWP) groundwater monitoring program (conducted from 1981 through 1987) revealed that TCE and PCE had contaminated approximately 50 percent of the water supply wells in the eastern SFVGB at concentrations exceeding Federal and state drinking water standards.

LASC has over 200 acres of aircraft manufacturing facilities located in Burbank, California. In addition, EPA has identified approximately 30 other potentially responsible parties associated with the Burbank/North Hollywood Well Field. Late 1987, solvent-contaminated soil and groundwater were identified near the Lockheed site. As a result, the California Regional Water Quality Control Board, Los Angeles Region, issued a Cleanup and Abatement order requiring soil and groundwater remediation to commence by August 1, 1988, and October 15, 1988, respectively.

The results of a monitoring program by the City of Burbank, which routinely samples several Public Service Department (PSD) wells in its vicinity indicated that TCE and PCE concentration levels in the groundwater exceeded the maximum contaminant levels (MCL), which are 5.0 **µg/L** for both TCE and PCE. Most of the PSD wells are within a 2-mile radius of the Lockheed site, with the wells closest to the site showing the greatest contamination. The groundwater treated during the AWD SITE demonstration was extracted from **an on-**site extraction well at the Lockheed site,

An operable unit feasibility study, performed by James M. Montgomery Consulting Engineers, Inc. (JMM) for LADWP in 1988, confirmed the presence of VOCs in a number of wells in the SFVGB. In addition to TCE and PCE, trace quantities of other VOCs, including methylene chloride, toluene, acetone, carbon tetrachloride, methyl ethyl ketone, and the trihalomethanes, chloroform, bromodichloromethane, anddibromochloromethane, weredetected (JMM, 1988).

Lockheed has routinely monitored the performance of the AWD treatment system in its Burbank site since the system became operational in September 1988. Influent and effluent groundwater and soil-gas samples are routinely collected and analyzed to ensure proper operation of the system. Samples from the first 10 months of operation showed groundwater TCE contamination in the 1,100 to 2,300 **µg/L** range and PCE contamination ranging from approximately 9,000 to as

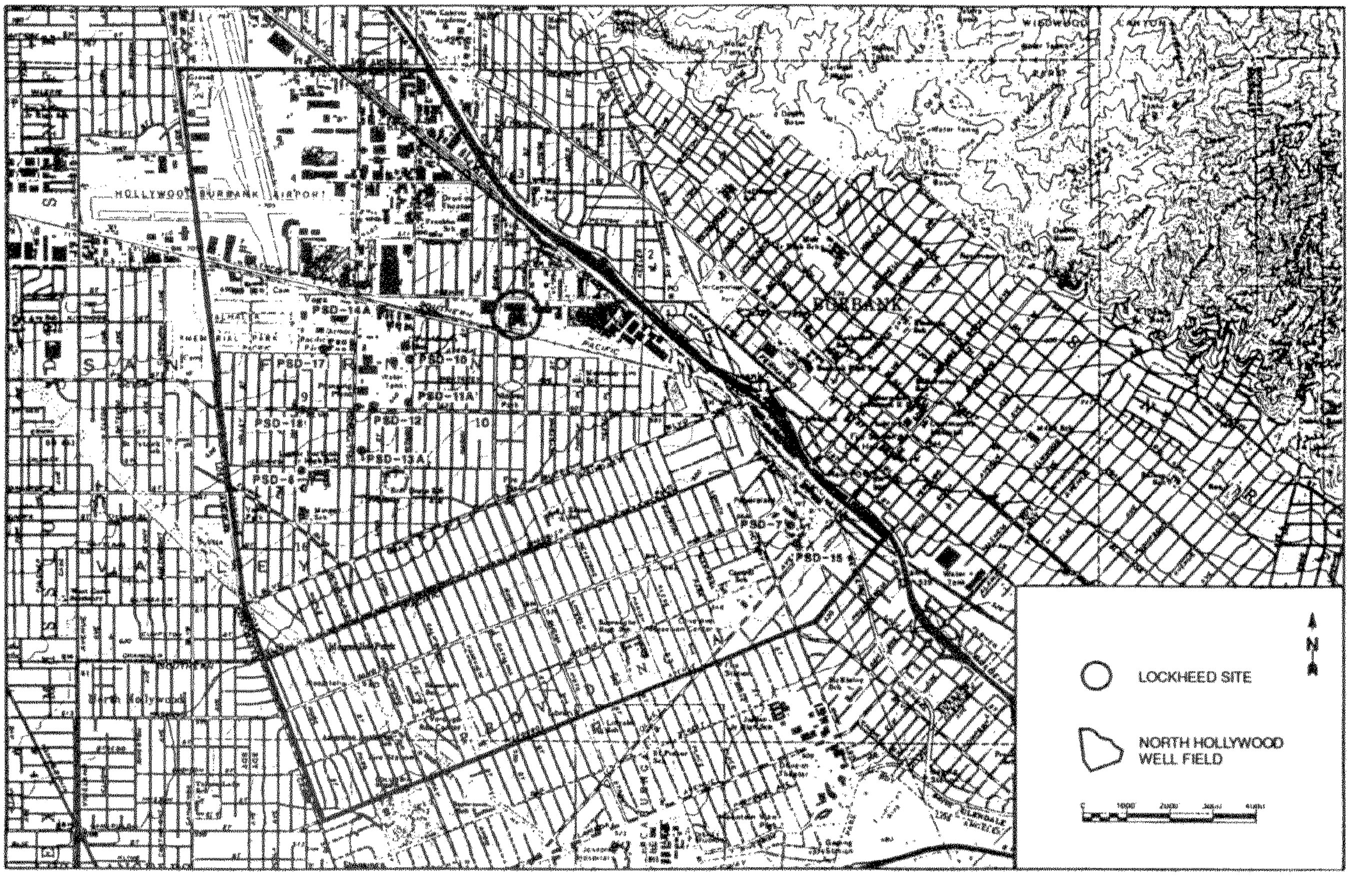

Figure C-1. North Hollywood Well Field Map.

high as 22,000 µg/L. During this period, soil-gas contamination was approximately 100 ppm for TCE and 6,000 ppm for PCE.

Concentrations of contaminants in the groundwater and soil-gas have dropped with continued operation of the system. Influent TCE and PCE concentrations observed during the demonstration were considerably less than those previously mentioned. Concentrations in the influent groundwater samples collected during the SITE demonstration were typically in the 400 to 600 µg/L range for TCE and 2,000 to 2,500 µg/L range for PCE. Soil-gas samples from the demonstration had concentrations of approximately 10 ppm for TCE and 400 ppm for PCE. No other VOCs were detected in the groundwater or soil-gas at the site.

Treatment System Performance

A review of the system's performance and any operational problems during the technology demonstration and a description of site preparation and demobilization efforts are presented in this section.

Site Preparation

Site preparation included minor modifications to the treatment system already on-site, and setup of on-

support services and utilities. Unlike most other SITE projects, the AWD technology was demonstrated by using an already-installed, operational system at the Lockheed site. As such, set up of the treatment system, system start up procedures and teardown of the system after completion of the demonstration were not required. However, the existing system was slightly modified for the demonstration.

The modifications included the addition of stainless steel sampling ports to the GAC beds to facilitate soil-gas sample collection and suspension of two normal operational practices for the duration of the 2-week demonstration. Sulfuric acid is normally added to the influent groundwater to prevent scaling problems in the

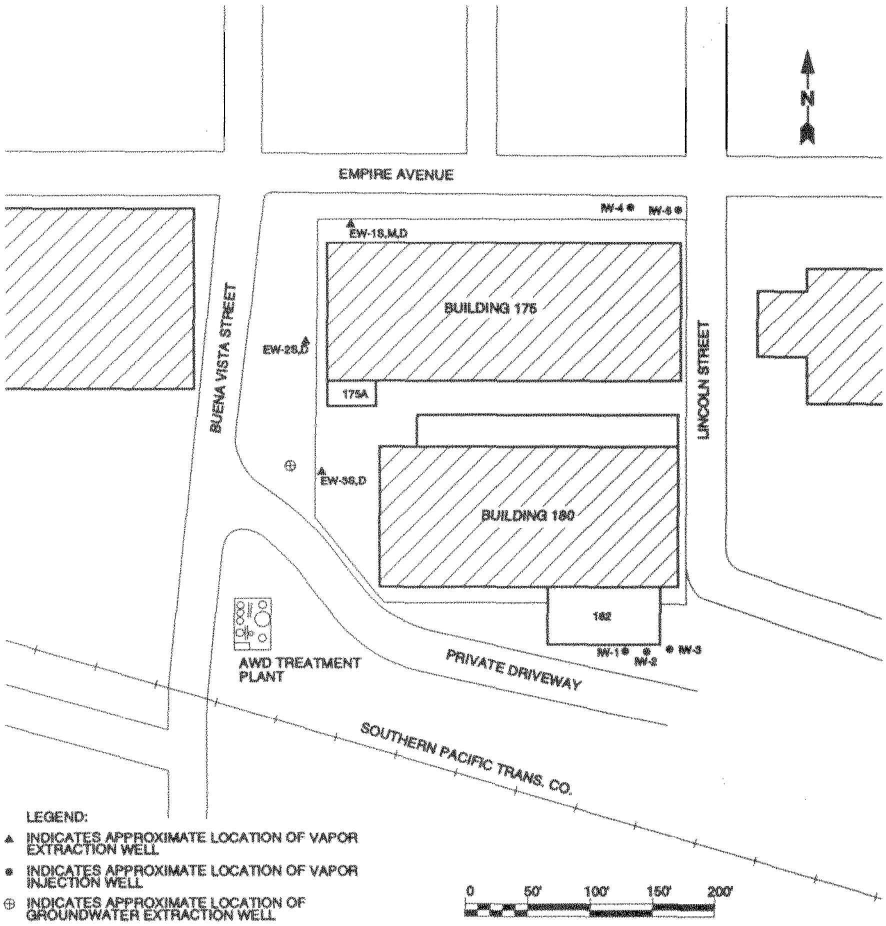

Figure C-2. Lockheed Site Location.

AquaDetox® stripping tower. Sulfuric acid addition was suspended during the demonstration to allow better control of the stripping tower pressure. The second suspended practice was the addition of the vacuum pump's lubricant to the recovered solvents. Typically a heavy lubricant is circulated through the vacuum pump and discharged to the recovered solvent at a very low flow rate. The lubricant was collected in a 55-gallon drum during the demonstration to minimize its effect on the quality of the recovered solvents.

On-Site Support Services

On-site laboratory analyses were conducted in a field trailer. The field trailer also served as an office for field personnel, provided shelter and storage for equipment and supplies, and acted as a base for site security personnel. Two portable toilets were located near the trailer. The trailer was equipped with a fax machine and a copy machine. Although the treatment system at the Lockheed site is enclosed by a fence and Lockheed security patrols the area periodically, a commercial security service was hired to provide additional protection from equipment theft or vandalism during the evening hours and weekends.

Utilities

All utilities required for the operation of the AWD system were obtained from sources at or near Lockheed facilities. Utilities required for the on-site office trailer included electrical and telephone services and water. Water was required for drinking and personnel decontamination. Bottled water was used for both purposes.

Telephone service was required to order supplies, coordinate site activities, and provide communication. Two telephone lines were installed in the trailer. An on-site diesel generator provided electricity to the office trailer. Canopies provided shelter from direct sunlight to the personnel, as well as the sampling equipment.

Technology Demonstration

The AWD Technology was demonstrated over a 2-week period in September 1990. The SITE demonstration consisted of 2 1 test runs performed under varying operating conditions. The test runs were grouped into six phases. Phase 1 test runs were performed at AWD-specified operating conditions (tower pressure at 105 mm Hg, steam flow rate at 3,800 lbs/hr, and groundwater flow rate at 900 gpm). The steam flow rate was varied in Phase 2 test runs. Steam flow rates and tower pressures were varied simultaneously in Phases 3 and 4. The groundwater flow rate was varied in Phase 5 test runs. Phase 6 involved the SVE system, in which the GAC bed regeneration frequency was varied. During the 2-week period, the demonstration schedule was significantly modified to accommodate several operational problems or limitations. Table C- 1 lists the operating conditions for each test run.

Operational Problems

Operational problems are grouped into two categories: (1) equipment related problems, and (2) nonequipment related problems. A description of each follows.

Equipment Related Problems

A dry run (a practice run where collected samples are not analyzed) was attempted on Friday, September 7. During the dry run it was determined that additional sampling ports were required to collect all the gas samples that were outlined in the demonstration plan. Stainless steel sampling ports were installed by contracted welders on the morning of September 10.

The demonstration was started in the afternoon of September 10, 1990. The system performed with no equipment related problems during the first 4 days of testing. However, a broken SVE blower prevented operation of the system on September 14. The replacement parts required to repair the broken blower were shipped by a supplier and were not available until

Table C-1. AWD SITE Demonstration Schedule and Test Run Conditions

Run Number	Phase Number	Groundwater Flow Rate (gpm)	Tower Pressure (mm Hg)	Steam Flow Rate (lb/hr)	GAC Bed Regeneration Period (hr)
1	1	900	105	3,800	8
2	2	900	105	3,750	8
3	2	900	105	3,700	8
4	2	900	105	3,850	8
5	1	900	105	3,800	8
6	3	900	150	4,800	8
7	3	900	125	4,350	8
8	3	900	160	5,100	8
9[a]	3	--	--	--	--
10[a]	3	--	--	--	--
11	1	900	105	3,800	8
12	4	600	105	2,600	8
13	4	600	95	2,400	8
14	4	600	85	2,200	8
15	4	600	75	2,000	8
16	1	900	105	3,800	8
17	5	600	105	2,600	8
18	5	700	105	2,700	8
19	5	800	105	3,300	8
20	5	970	105	4,100	8
21	1	900	105	3,800	8
GAC-A	6	900	105	3,800	16
GAC-B	6	900	105	3,800	24

[a] These runs were not performed because the desired conditions could not be attained.

the morning of September 18. The blower was fixed in the afternoon and demonstration activities resumed. Even though Lockheed stocks many spare parts on-site, it is not practical for Lockheed to store every spare part to avoid an extended down time as occurred during the SITE demonstration.

Another equipment related problem was the performance of the system at higher tower pressures. High stripping tower pressure runs in Phase 3 (Runs 9 and 10) had to be modified or cancelled altogether because the system could not reach steady state conditions or it would shut down completely.

Runs 9 and 10 were originally planned to operate at pressures of 300 and 350 mm Hg, respectively. However, these tower pressures were unattainable and the test runs were canceled. At 300 mm Hg, the operating temperature of the stripping tower was increased by 24°C due to the higher boiling point of water at this pressure. The effluent groundwater exiting the stripping tower at this higher temperature was causing cavitation problems in the groundwater pump. Pump cavitation occurs as liquid enters the pump chamber and literally boils or vaporizes due to the low pressure conditions within the chamber.

To avoid the pump cavitation problem the conditions for Runs 7 and 8 were modified. However, it was difficult to maintain the stability of the system even at a relatively low pressure range of 150 to 160 mm Hg. The vacuum pump at the Lockheed site operates at full capacity at all times. To achieve pressures in the 150 to 160 mm Hg range, a control valve used to adjust the intensity of the vacuum was nearly shut. Therefore, even small adjustments to the control valve impacted the tower pressure significantly. Consequently, steady state conditions took considerably longer to achieve and were difficult to maintain in these runs.

Nonequipment Related Problems

The demonstration schedule was modified several times due to the unusually hot weather during the first week of testing. Mid-day temperatures in excess of 100°F during the first week of the demonstration greatly reduced the effectiveness of the vacuum pump. Many of the runs requiring a pressure of 105 mm Hg or lower were postponed or were performed early in the morning to avoid problems related to the high ambient temperatures.

Another nonequipment related problem was the interruption of Run 2 when it was discovered that the incorrect operating parameters were set. The correct operating parameters were then established and Run 2 was restarted.

Demobilization

As previously mentioned, tear down and demobilization of the treatment system equipment was not required for this project. Removal of the on-site office trailer, utilities, and related equipment was accomplished within the first week after completion of the demonstration.

Contaminated materials, such as empty sample containers, laboratory wastes, and disposable protective equipment generated during the demonstration, were placed in a 55-gallon, open-top drum. These materials contained only residual contamination.

Review of Treatment Results

The AWD technology demonstration involved: (1) performing tests on appropriate process streams with operating parameters set at AWD-specified values to confirm that the system is viable for use at Superfund sites and (2) evaluating the ability of the system to remove VOCs from groundwater and soil-gas under varying operating conditions. The operating parameters, including the steam flow rate, stripping tower pressure, groundwater flow rate, and GAC bed regeneration frequency, were varied throughout the demonstration, and the system's performance was evaluated under each set of operating conditions.

The AWD system is designed to treat VOC-contaminated groundwater and soil. In addition, the only organics detected at the site were TCE and PCE. Therefore, the major performance criterion for this demonstration was percent removal of TCE and PCE from contaminated groundwater and soil-gas. The system's compliance with groundwater regulatory discharge requirements for TCE and PCE (5 $\mu g/L$ each) was also monitored.

Quantifiable Results

The AWD technology achieved removal efficiencies as high as 99.99 percent for both TCE and PCE from the groundwater. On the average, the removal efficiencies were slightly higher for PCE than TCE (Figure C-3). Removal efficiencies for total VOCs (TCE and PCE) ranged from 99.92 to 99.99 percent (Table C-2).

The three runs with the lowest removal efficiencies, Runs 11, 18, and 19, were all performed on September 18 after the system was inoperable for 4 days. The system may not have been operating efficiently after being shut down for several days.

removes the majority of the VOC contamination from the soil-gas. The secondary GAC bed, functioning as a fail-safe device removes any remaining contamination. It is therefore, expected that the VOC concentrations be higher in the effluent of the primary GAC bed.

Based on sample collection information, it was determined that VOC concentrations were higher in the secondary GAC bed effluent only when GAC bed No. 3 was being used as the secondary bed. Two possible

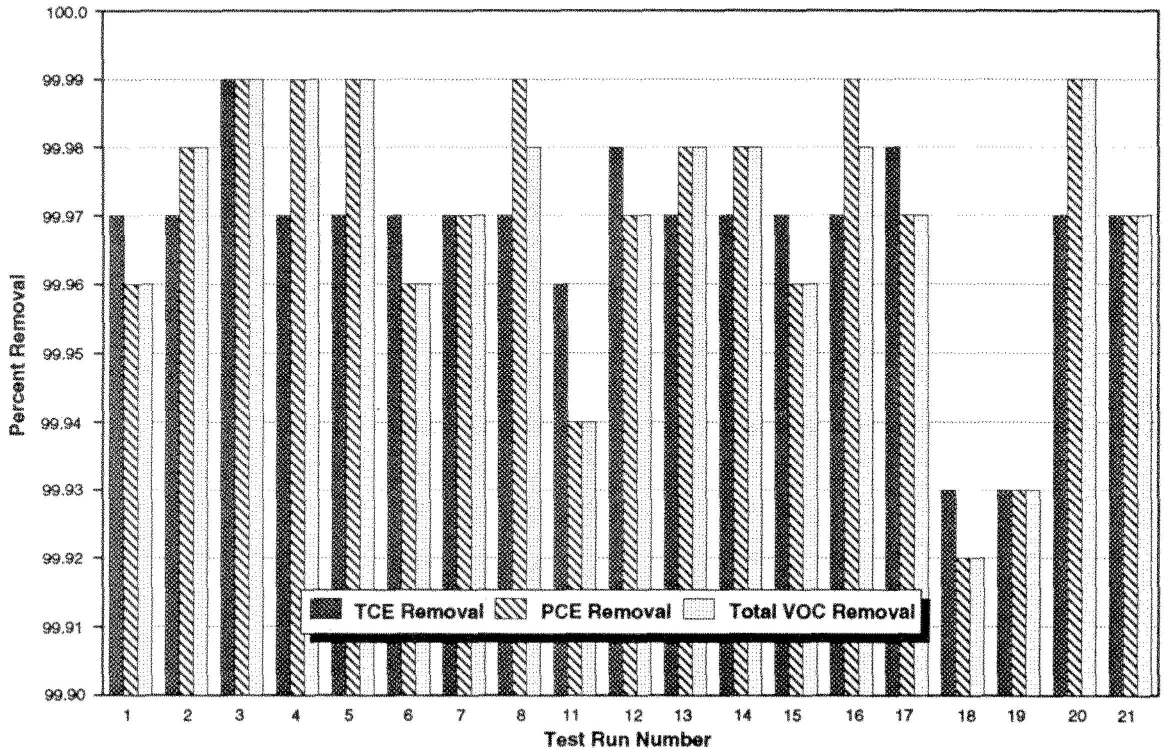

Figure C-3. Percent Removal of VOCs from Groundwater for all Test Runs.

Removal efficiencies for total VOCs from soil-gas ranged from a low of 93.4 percent to as high as 99.9 percent (Figure C-4). As expected, lower removal efficiencies were observed when the GAC beds were regenerated less frequently (Phase 6 Runs GAC-A and GAC-B). However, even after 24 hours of operation without steam regeneration, the primary GAC bed removed more than 99 percent of VOCs from the soil-gas.

As shown in Table C-3, for several runs (those with a negative percent removal in the secondary GAC bed) the effluent from the first on-line GAC bed was actually cleaner than the effluent from the second on-line bed. As the primary GAC bed, the first on-line GAC bed

explanations exist: (1) GAC bed No. 3 was not performing as designed or (2) the samples were collected in the incorrect order. That is, the primary GAC bed effluent samples were labeled as the secondary bed effluent and vice versa. The removal efficiencies listed in Table C-3 were calculated based on the first explanation. However, if the samples were collected in the wrong order, the removal efficiencies would be even higher.

SVOCs, PCBs, and other were not detected in groundwater samples. Total organic carbon (TOC) and total dissolved solids (TDS) analyses were also performed. SVOC, PCB, TOC, and TDS analyses were only performed for the first test run. Alkalinity,

Table C-2. Summary of Total Groundwater TCE and PCE Concentrations and Percent Removal Data

Run No.	Influent Concentrations (µg/L) TCE	PCE	Total	Effluent Concentrations (µg/L) TCE	PCE	Total	Total %Removed
1	488	2010	2500	0.15	0.80	0.95	99.96
2	489	1930	2420	0.15	0.43	0.58	99.98
3	498	2080	2580	0.15	0.20	0.35	99.99
4	562	1920	2470	0.15	0.20	0.35	99.99
5	522	2080	2610	0.15	0.20	0.35	99.99
6	495	2170	2670	0.15	0.93	1.08	99.96
7	542	2100	2640	0.15	0.53	0.68	99.97
8	548	2390	2940	0.15	0.33	0.48	99.98
9[a]	--	--	--		--		--
10[a]	--	--	--		--		--
11	530	2770	3300	0.20	1.67	1.87	99.94
12	620	2520	3140	0.15	0.70	0.85	99.97
13	554	2320	2870	0.15	0.43	0.58	99.98
14	544	2550	3090	0.15	0.43	0.58	99.98
15	544	2620	3160	0.15	1.13	1.28	99.96
16	491	2420	2910	0.15	0.33	0.48	99.98
17	620	2520	3140	0.15	0.70	0.85	99.97
18	615	2800	3420	0.43	2.37	2.80	99.92
19	814	4080	4900	0.53	2.70	3.23	99.93
20	515	2130	2650	0.15	0.20	0.35	99.99
21	475	2080	2550	0.15	0.67	0.82	99.97

[a] These runs were not performed because the desired conditions could not be attained

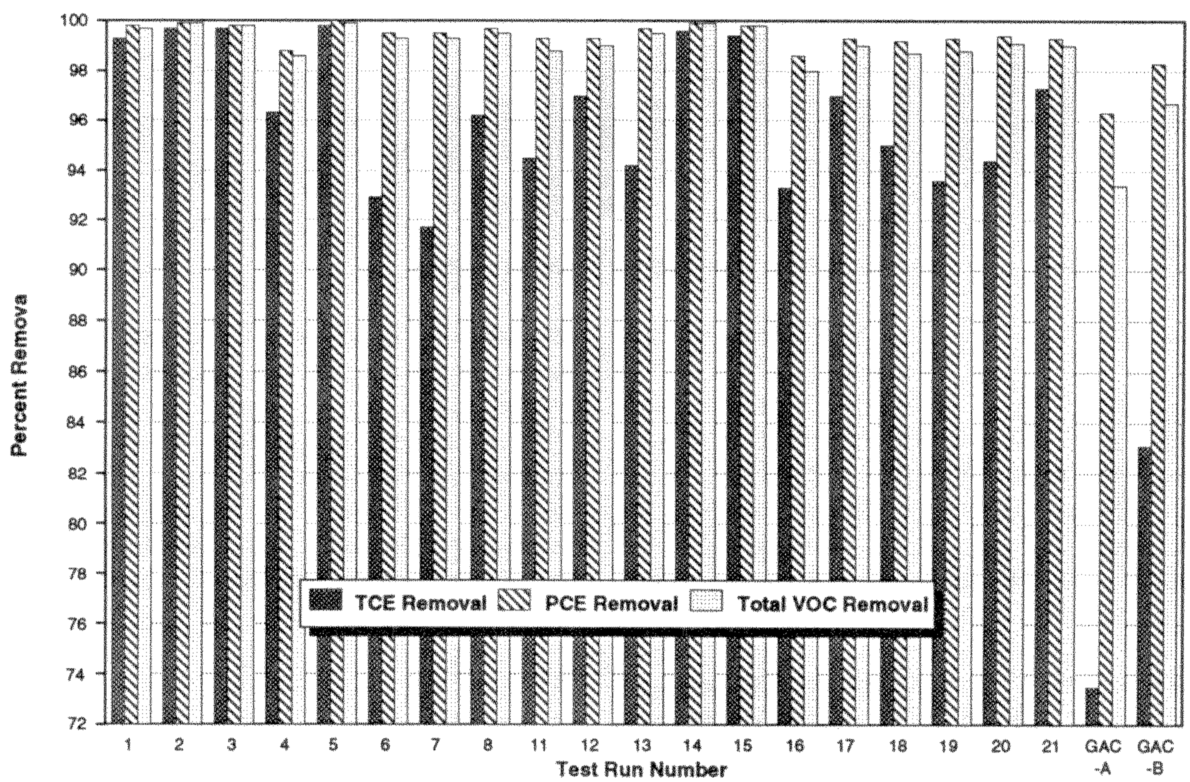

Figure C-4. Percent Removal of VOCs from Soil-Gas for all Test Runs.

Table C-3. Summary of Total Soil-Gas TCE and PCE Concentrations and Percent Removal Data

Run	Primary GAC Bed Conditions			Secondary GAC Bed Conditions			Total
No.	Influent (ppmv)	Effluent (ppmv)	%Removed	Influent (ppmv)	Effluent (ppmv)	%Removed	%Removed
1	643	0.00	100.	0.00	1.74	NEG[a]	99.7
2	968	5.53	99.4	5.53	1.23	77.8	99.9
3	566	3.04	99.5	3.04	1.32	56.6	99.8
4	922	0.938	99.9	0.938	13.0	NEG	98.6
5	1270	5.77	99.5	5.77	0.706	87.8	99.9
6	864	1.79	99.8	1.79	6.37	NEG	99.3
7	1080	1.35	99.9	1.35	7.95	NEG	99.3
8	1210	1.24	99.9	1.24	6.13	NEG	99.5
9[b]	--	--	--	--	--	--	--
10[b]	--	--	--	--	--	--	--
11	675	15.6	97.7	15.6	8.25	47.1	98.8
12	586	6.80	98.8	6.80	5.94	12.6	99.0
13	1190	3.80	99.7	3.80	6.24	NEG	99.5
14	606	17.4	97.1	17.4	0.884	94.9	99.9
15	730	15.6	97.9	15.6	1.69	89.2	99.8
16	726	0.930	99.9	0.930	14.4	NEG	98.0
17	586	6.80	98.8	6.80	5.94	12.6	99.0
18	993	1.33	99.9	1.33	12.6	NEG	98.7
19	1030	0.800	99.9	0.800	12.3	NEG	98.8
20	1350	1.04	99.9	1.04	11.7	NEG	99.1
21	846	1.41	99.8	1.41	8.16	NEG	99.0
GAC-A	863	4.11	99.5	4.11	57.1	NEG	93.4
GAC-B	389	3.37	99.1	3.37	13.0	NEG	96.7

[a] Concentrations were higher in the secondary GAC bed effluent, resulting in negative removal efficiencies.
[b] These runs were not performed because the desired conditions could not be attained.

hardness, and pH measurements were performed for all test runs. Hardness and pH values did not change significantly after treatment. Alkalinity values were lower in the effluent groundwater samples.

To eliminate the steam supply as a possible source of contamination, condensed steam samples were collected on the first and last day of the demonstration. TCE and PCE concentrations for both steam samples were below the detection limit.

Ninety-five percent upper confidence limit (UCL) values for effluent groundwater TCE and PCE concentrations were compared with the regulatory discharge requirement for each compound for all test runs. Although the operating conditions in some test runs were less than optimum, the effluent from all test runs met the regulatory discharge requirement. Figure C-S shows the UCL for each VOC and how it compares with the regulatory discharge requirement in each test run.

Final Products of the Treatment Process

The final products of the AWD technology include the treated groundwater and soil-gas, recovered VOCs, and spent carbon from the GAC beds. Although the carbon in the GAC beds at the Lockheed site has not required replacement in over 2 years of operation, it is estimated that GAC replacement may become necessary after approximately 3 years of operation. The recovered VOCs are collected in an on-site storage tank and periodically trucked to an off-site recycler. During the SITE demonstration approximately 17 pounds of VOCs were recovered from the groundwater, as well as the soil-gas (34 pounds total).

Accomplishing the Goals of the Technology Demonstration

Specific goals for the AWD technology demonstration, and an evaluation of how those goals were met, are discussed below.

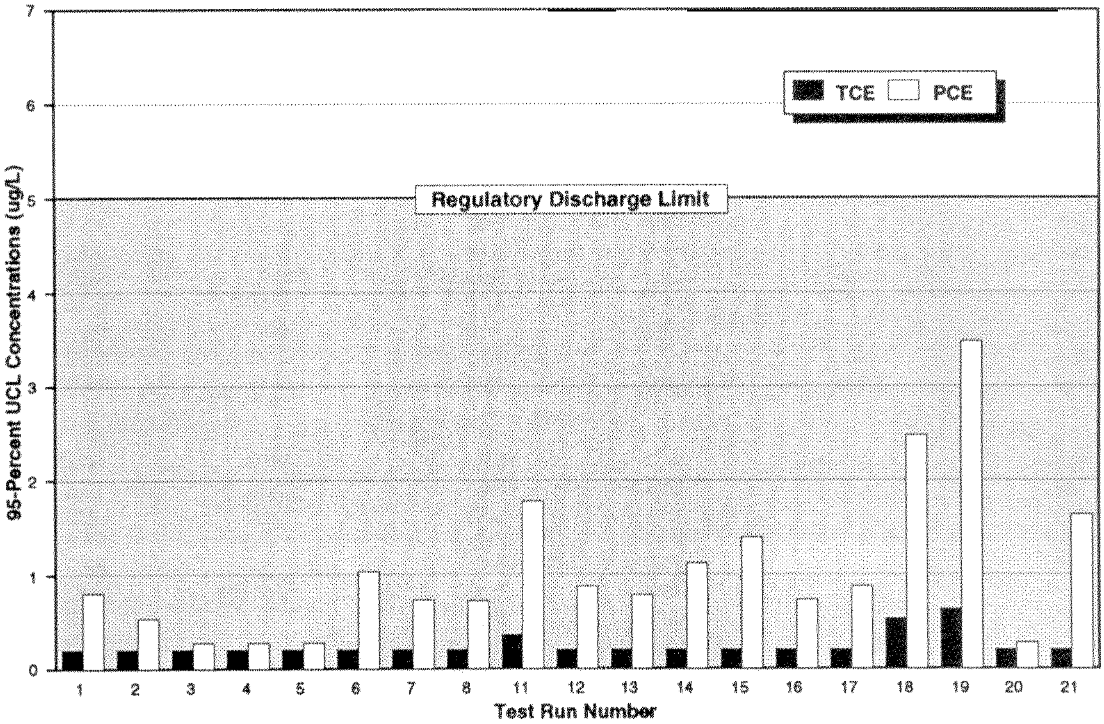

Figure C-5. 95-Percent Upper Confidence Limits of TCE and PCE Concentrations in Effluent Groundwater Samples for all Test Runs.

1. Goal: Evaluate the performance of the AWD system and its removal efficiencies for VOCs from groundwater and soil-gas at AWD-specified operating conditions and under varying operating conditions.

   Result: The AWD system successfully treated VOCs present in the groundwater and soil-gas at the Lockheed site. Removal efficiencies as high as 99.99 percent were achieved for total VOCs present in the groundwater. Removal efficiencies were as high as 99.9 percent for total soil-gas VOCs.

2. Goal: Monitor the compliance of the AWD system with regulatory discharge requirements.

   Result: The effluent groundwater from all test runs met the regulatory discharge requirements for both TCE and PCE. Other organics were not detected.

3. Goal: Develop capital and operating costs for the system.

   Result The AWD system costs approximately $3.2, $4.3, and $6.0 million (1991$), for the 500-, 1,000-, and 3,000-gpm systems, respectively. The total annual operation and maintenance (O&M) costs are approximately $5 10,000, $820,000, and $2,000,000 (1991$) for the 500-, 1,000-, and 3,000-gpm systems, respectively.

4. Goal: Identify specific operating and maintenancee concerns.

   Result: Problems with the SVE blower shut down the system for 4 days. This and other operational problems were noted.

References

James M. Montgomery Consulting Engineers, Inc., 1988. Remedial Investigation of the San Fernando Valley Groundwater Basin, Operable Unit Feasibility Study, Burbank Well Field. JMM, October 1988.

PRC Environmental Management, Inc., 1990. Demonstration Plan for the AWD Technologies Integrated **AquaDetox®/SVE** Technology. Prepared for U.S. EPA, RREL, Cincinnati, Ohio, by PRC SITE Team, September 1990.

Appendix D
Case Studies

Appendix D Contents

Appendix D
Case Studies

Introduction

This appendix summarizes several case studies on the use of AWD Technologies' treatment systems that have been tested at five sites. Unlike the integration of the **AquaDetox®/SVE** treatment systems at the Lockheed facility in Burbank, four of these case studies involve the separate applications of these treatment components. The fifth case study presents the results of a test run conducted by the California Department of Health Services on the integrated system at the Burbank facility. This appendix summarizes the following case studies:

Study	System and Location
D-l	In-Situ Soil Vapor Extraction System, Northern California
D-2	**AquaDetox®** Groundwater Treatment, Southern California
D-3	**AquaDetox®** Vacuum Steam Stripping System, King of Prussia, Pennsylvania
D-4	**AquaDetox®** Technology, Kalkaska, Michigan
D-5	Integrated **AquaDetox®/SVE** Treatment System, Burbank, California

Case Study D-l In-Situ Soil Vapor Extraction System, Northern California

PROJECT:	In-Situ Soil Vapor Extraction System
CLIENT:	Confidential
LOCATION:	Northern California
PERFORMANCE PERIOD:	1989 - Present
ASSIGNMENT:	Design/Construct/Operate Soil Vapor Extraction System

This site was previously an industrial warehouse. Significant soil contamination identified at various soil boring locations was confined to a small area at the site. Soil is mainly comprised of silty sand to a depth of 5 feet. The major volatile organic compounds involved are toluene, TCE, and l,l,l-trichloroethane. A vapor extraction system furnished with four in-line extraction wells, vacuum blower, moisture trap, and emission control unit was constructed to remove soil vapor in the vadose zone. An in-situ vapor extraction test was performed using the four in-line wells to evaluate the feasibility of the soil treatment via vapor removal. One well was used as the extraction well and the remaining three wells served as monitoring wells. An explosion proof vacuum blower removed soil-gas at a rate of approximately 100 scfm during the test. The vacuum head applied to the extraction well measured 40 inches of water and the most distant monitoring well, 30 feet away from the vacuum well, measured inches of water. Three monitoring wells had almost instant response to the applied vacuum.

The vacuum measured in these wells was within a range of 5 to 6 inches of water. Therefore, the radius of influence caused by the applied vacuum was estimated beyond 30 feet from the vacuum source. From this result, the in-situ vapor extraction method was shown to be an effective remedial technique for soil contamination at the site.

A permit was obtained from the Bay Area Air Quality Management District in September 1989. The vapor extraction system has been in operation since and maintained volatile organic emission at below detection limit,

Case Study D-2
AquaDetox® Groundwater Treatment, Southern California

PROJECT:	AquaDetox® Groundwater Treatment
CLIENT:	Confidential
LOCATION:	Southern California
PERFORMANCE PERIOD:	1988 - 1989
ASSIGNMENT:	Design and Construction of Groundwater Treatment System

A major manufacturing corporation retained AWD Technologies, Inc., to design and construct a groundwater remediation system to treat high concentrations of PCE and TCE at a depth of 25 feet.

The company had planned to expand its existing treatment system--one stripping tower with a carbon bed adsorption unit--to four parallel trains with two stripping towers each and a carbon adsorption unit for each train. AWD significantly reduced the number of stripping towers required to process the contaminated water by using AquaDetox® technology. AWD's final design uses three parallel trains with one stripping tower each and a set of carbon adsorption units servicing all three trains. AWD incorporated the existing stripping tower and carbon adsorption unit into the design. The two additional stripping towers--a conventional 300 gpm air stripper and a 600 gpm AquaDetox® moderate vacuum unit--and the new set of carbon adsorption units completed the system.

Contaminated groundwater is piped to the treatment system from off-site extraction wells near the head of the plume three-fourths of mile west of the site and from on-site extraction wells near the source of the contamination. Contaminated air is purified with carbon adsorption before being vented to the atmosphere. The entire process is controlled by a state-of-the-art instrumentation system.

Case Study D-3
AquaDetox® Vacuum Steam Stripping System, King of Prussia, Pennsylvania

PROJECT:	AquaDetox® Vacuum Steam Stripping System
CLIENT:	Ciba-Geigy Corporation
LOCATION:	King of Prussia, Pennsylvania
PERFORMANCE PERIOD:	1988 - Present
ASSIGNMENT:	Design and Construction of Groundwater Treatment System

AWD Technologies, Inc., was retained by Ciba-Geigy Corporation to permit, pilot test, design, construct, and operate a vacuum steam stripping system to treat contaminated groundwater at the Tyson's Dump Superfund Site.

The Tyson's Dump site is an abandoned septic waste and chemical waste disposal site reported to have operated form 1976 to 1980 within a sandstone quarry, approximately 200 yards from the Schuyhill River. In September 1983, the site was added to the National Priority List. Between January 1983 and August 1984, EPA and its contractors conducted a series of investigations primarily in what is referred to as the "On-Site" area which includes two former lagoon areas. Samples showed the presence of chemical contamination within the soil column from the surface extending down to bedrock.

In 1985, further investigation of the off-site area was undertaken that included the underlying groundwater. The groundwater was found to be contaminated with organics. Major contaminants were 1,2,3-

trichloropropane at levels exceeding 100,000 ppb, total xylenes, aniline, and phenol.

As an interim remedial measure to clean the groundwater, carbon adsorption units were installed at the site. In 1988, the PRP committee retained AWD Technologies, Inc., to design and construct a groundwater treatment system to provide a long-term solution.

AWD performed an **AquaDetox®** pilot simulation at Dow Chemical's research laboratory in Midland, Michigan. Based on the simulation, AWD designed a 5OO-gpm **AquaDetox®** vacuum steam stripping system with recovered organics storage.

AWD began construction of the system in September 1989. Work included site work, foundations, building, utility services, and the **AquaDetox®** stripping tower. The system began operating in March 1990. AWD is currently operating the system.

Case Study D-4
Aqua Detox® Technology, Kalkaska, Michigan

PROJECT:	**AquaDetox®** Technology
CLIENT:	The Dow Chemical Company
LOCATION:	Kalkaska, Michigan
ASSIGNMENT:	Design and Build Groundwater Treatment System

The Dow Chemical Company selected the site of a former Dowel1 facility in Kalkaska, Michigan, to apply its **AquaDetox®** technology to a major groundwater cleanup operation. The major contaminant was toluene which had leaked from a faulty fitting. The leak had proceeded an undetermined number of years, creating a large plume. The initial concentration in the plume was over 10 ppm toluene. **AquaDetox®** technology was favored over traditional carbon bed adsorption because of its high efficiency and low cost.

An **AquaDetox®** system was installed to treat groundwater recovered from purge wells within the plume. The system was set up to handle pumping rates between 25 and 100 gpm and was generally operated at 30 to 40 gpm. The initial concentration of 10 ppm toluene in 1984 is now down to less than 4 ppb, approaching the laboratory detection limit. Some of the purge wells are now being phased out as water quality improves. The cost of treating the water by **AquaDetox®** was about $1 to $2 per 1,000 gallons compared to approximately $20 per 1,000 gallons for carbon bed adsorption.

Case Study D-5
Integrated AquaDetox®/SVE Treatment System, Burbank, California

PROJECT:	**AquaDetox®/SVE** Treatment System
CLIENT:	Lockheed Aeronautical Systems Company
LOCATION:	Burbank, California
PERFORMANCE PERIOD:	January - March 1990
ASSIGNMENT:	Participate in Demonstration by State of California, Department of Health Services

This case study reviews AWD's integrated **AquaDetox®/SVE** treatment system operating at the Lockheed site over a six week period in early 1990. The study was part of California's Toxic Substances Control Program, alternative Technology Division under the state's Department of Health Services. Their evaluation included calculating the contaminant removal efficiencies of the **AquaDetox®** and SVE systems separately and determining an overall contaminant mass balance on the integrated system.

During the course of the demonstration which began on January 22,199O and ended on March 5,1990, influent and effluent groundwater samples were collected weekly and analyzed for VOCs and general water quality parameters. Influent and effluent soil-gas samples were collected biweekly and analyzed for VOCs. For the purpose of conducting a mass balance, levels in the solvent storage tank, liquid phase separator's boot, and soil-gas vapor/liquid separator tank were recorded before and after the test.

The average overall contaminant removal efficiency of the **AquaDetox®** system was 99.87 percent. Average removal efficiencies for PCE and TCE were 99.98 and 99.94 percent, respectively. The average overall contaminant removal efficiency of the SVE system was 99.65 percent with average removal efficiencies of 99.72 and 98.11 percent for PCE and TCE, respectively. The overall total calculated recovery of contaminants was 6 percent higher than the actual quantity recovered. Comparing the influent and effluent waters, there were significant changes in chloride, sulfate, nitrate, and boron. The effluent's temperature was approximately 6 to 9°C higher than the influent and had slightly lower hardness and alkalinity than that of the influent water. The effluent's pH was approximately 1 pH unit higher than that of the influent. Total dissolved solids of the effluent were lower than that of the influent.

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